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(54) Title: PEPTIDE WHICH ABROGATES TNF AND/OR LPS TOXICITY

VRSSSRTPSD10KPVAHVVANP20QAEGQLQWLN30RRA

NALLANG40VELRDNQLVV50PSEGLYLIYS60QVLFKGQGCP70STHVLL

THTI80SRIAVSYQTK90VNLLSAIKSP100CQRETREGAE110AKPWYEPI

YL120GGVFQLEKGD130RLSAEINRPD140YLDFAESGQV150YFGIIAL157

(57) Abstract

The present invention provides peptides which have the ability to abrogate TNF toxicity and/or LPS toxicity. The present invention further relates to compositions including these peptides as the active ingredient and methods of anti-inflammatory treatment involving the administration of this composition. The peptides f the present inventi n are based primarily on residue 1 to 26 of human TNF.

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PEPTIDE WHICH ABROGATES TNF AND/OR LPS TOXICITY

Field of the Invention

The present invention relates to a group of peptides which have the ability to abrogate TNF toxicity and/or LPS toxicity. The present invention further relates to compositions including this peptide as the active ingredient and methods of anti-inflammatory treatment involving the administration of this composition.

Background of the Invention

Many of the clinical features of septicemic shock induced by Gram-negative bacteria which have lipopolysaccharide (LPS) in their cell walls may be reproduced in animals by the administration of LPS. This induces prompt severe metabolic and physiological changes which can lead to death. Associated with the injection of LPS is the extensive production of tumour necrosis factor alpha (TNF). Many of the effects of LPS injection or indeed of Gram-negative bacteria can be reproduced by TNF. Thus, mice injected with recombinant human TNF develop piloerection of the hair (ruffling), diarrhoea, a withdrawn, unkempt appearance and die if sufficient amounts are given. Rats treated with TNF become hypotensive, tachypneic and die of sudden respiratory arrest (Tracey et al., 1986 Science 234, 470). Severe acidosis, marked haemoconcentration and biphasic changes in blood glucose concentration were also observed. Histopathology revealed severe leukostatsis in the lungs, haemorraghic necrosis in the adrenals, pancreas and other organs and tubular necrosis of the kidneys. All these changes were prevented if the animals were pretreated with a neutralizing monoclonal antibody against TNF.

The massive accumulation of neutrophils in the lungs of TNF-treated animals reflects the activation of neutrophils by TNF. TNF causes neutrophil degranulation, respiratory burst, enhanced antimicrobiocidal and

anti-tumour activity (Klebanoff et al., 1986 J. Immunol. 136, 4220; Tsujimoto et al., 1986 Biochem Biophys Res Commun 137, 1094). Endothelial cells are also an important target for the expression of TNF toxicity. TNF diminishes the anticoagulant potential of the endothelium, inducing procoagulant activity and down regulation of the expression of thrombomodulin (Stern and Nawroth, 1986 J Exp Med 163, 740).

TNF, a product of activated macrophages produced in response to infection and malignancy, was first identified as a serum factor in LPS treated mice which caused the haemorraghic necrosis of transplantable tumours in murine models and was cytoxoic for tumour cells in culture (Carswell et al., 1975 PNAS 72, 3666; Helson et al., 1975 Nature 258, 731). Cachexia is a common symptom of advanced malignancy and severe infection. It is characterised by abnormal lipid metabolism with hypertriglyceridemia, abnormal protein and glucose metabolism and body wasting. Chronic administration of TNF (also known as cachectin in the early literature) to mice causes anorexia, weight loss and depletion of body lipid and protein within 7 to 10 days (Cerami et al., 1985 Immunol Lett 11, 173, Fong et al., 1989 J Exp Med 170, 1627). These effects were reduced by concurrent administration of antibodies against TNF. Although TNF has been measured in the serum of patients with cancer and chronic disease associated with cachexia the results are inconclusive since large differences in TNF levels have been reported. These may be due to the short half-life of TNF (6 minutes), differences in TNF serum binding protein, or true differences in TNF levels in chronic disease states.

TNFα, as a mediator of inflammation, has been implicated in the pathology of other diseases apart from toxic shock and cancer-related cachexia. TNF has b en

measured in synovial fluid in patients with both rheumatoid and reactive arthritis and in the serum of patients with rheumatoid arthritis (Saxne et al., 1988 Arthrit. Rheumat. 31, 1041). Raised levels of TNF have been detected in renal transplant patients during acute rejection episodes (Maury and Teppo 1987 J. Exp Med 166, 1132). In animals TNF has been shown to be involved in the pathogenesis of graft versus host disease in skin and gut following allogeneic marrow transplantation. Administration of a rabbit anti-murine TNF was demonstrated to prevent the histological changes associated with graft versus host disease and reduced mortality (Piquet et al., 1987 J Exp Med 166, 1280).

TNF has also been shown to contribute significantly to the pathology of malaria (Clark et al., 1987; Am. J. Pathol. 129: 192-199). Further, elevated serum levels of TNF have been reported in malaria patients (Scuderi et al., 1986; Lancet 2: 1364-1365). TNF may also contribute to the brain pathology and consequent dementia observed in late stage HIV infections (Grimaldi et al Ann Nevrol 29 : 21)

The peptides encompassed in the present invention do not necessarily interfere directly with the bio-synthetic mechanisms of the disease-causing component. As will be described below in the experimental data the mechanism behind the alleviating effect of the peptides is to be found in the modulation of the different cytokines produced by activated cells belonging to the cell-lines encompassing the immune defence. This modulation of cytokines is not limited to TNF but may also be valid for the whole range of interleukins, from interleukin-1 to interleukin 10. LPS, a known component of bacteria important in inducing major inflammatory response was used as a model. LPS binds to receptors on neutrophils, monocytes, endothelial cells and machrophages, which

consequently become activated and start production of IL-1 and TNF and other cytokines, thus starting the inflammatory cascade. One parameter used to measure the effect of LPS is the concentration of blood glucose, which will normally decrease on exposure to TNF or LPS.

LPS normally combines with LPS-Binding-Protein (LBP) and exerts its dramatic effect through the CD14 receptor. The activation of the CD14 molecule by LPS results in TNF production by leucocytes. It is believed that the peptides of the present invention which abrogate LPS toxicity may exert their effect by interacting with the CD14 molecule and thus inhibit LPS binding.

The peptides identified by the present inventors which have the ability to abrogate TNF and/or LPS toxicity resemble peptide sequences found in the amino terminal of TNFα . Other investigators have also considered this area of the TNFα molecule but with little success in obtaining biologically active peptides.

In this regard attention is drawn to Canadian patent application Nos 2005052 and 2005056 in the name of BASF AG. Both these applications claim a wide range of peptide sequences and, by selecting appropriate alternatives it can be seen that application No 2005052 is directed toward the peptide sequence 7-42 of TNFα whilst application No 2005056 is directed toward amino acid sequence 1 to 24 of TNFα . Whilst each of these applications claim a broad range of peptide sequences it is noted that there is no indication as to what, if any, biological activity the claimed peptides may possess. Indeed there is no demonstration that any of the produced peptide have any biological activity. In contrast, the present inventors have produced a range of peptides which have specific activities in that they abrogate TNF and/or LPS toxicity.

Summary of the Invention

In a first aspect the present invention consists in a linear or cyclic peptide of the gen ral formula:-

X_1-X_2-X_3-X_4-X_5-X_6-X_7-X_8-X_9

in which

X_1 is null, Cys or R_1

X_2 is null, Cys, R_1 or A_1-A_2-A_3-A_4-A_5

in which A_1 is Val or Ile or Leu or Met or His

A_2 is Arg or Cys or His

A_3 is Ser or Thr or Ala

A_4 is Ser or Thr or Ala

A_5 is Ser or Thr or Ala

X_3 is Cys, R_1 or A_6=A_7

in which A_6 is Arg or Cys or His or Absent

A_7 is Thr or Ser or Ala

X_4 is Cys, R_1 or A_8-A_9

in which A_8 is Pro or an Nα-alkylamino acid

A_9 is Ser or Thr or Ala

X_5 is Cys, R_1 or A_{10}

in which A_{10} is Asp or Ala or Cys or Glu or Gly or Arg or His

X_6 is Cys, R_2 or A_{11}-A_{12}-A_{13}

in which A_{11} is absent or Cys or Arg or His or Asp or Glu

A_{12} is Pro or an Nα-alkylamino acid

A_{13} is Val or Ile or Phe or Tyr or Trp or His or Leu or His or Met

X_7 is null, Cys, R_2 or A_{14}-A_{15}

in which A_{14} is Ala or Val or Gly or Ile or Phe or Trp or Tyr or Leu or His or Met

A_{15} is absent or His or Arg or Glu or Asa or Ala or Lys or Asp or Phe or Tyr or Trp or Glu or Gln or Ser or Thr or Gly

X_8 is null, Cys, R_2, A_{16}, A_{16}-A_{17}, A_{16}-A_{17}-A_{18} or A_{16}-A_{17}-A_{18}-A_{19}-A_{20}-A_{21}-A_{22}-A_{23}-A_{24}-A_{25}-A_{26}

in which A_{16} is Val or Ile or Leu or Met or His

A_{17} is Val or Ile or Leu or Met or His

A_{18} is Ala or Gly

A_{19} is Asp or Glu
A_{20} is Pro or an Nα-alkylamino acid
A_{21} is Gln or Asn
A_{22} is Ala or Gly
A_{23} is Glu or Asp
A_{24} is Gly or Ala
A_{25} is Gln or Asn
A_{26} is Leu or Ile or Val or Met or His

X_9 is null, Cys or R_2

R_1 is R-CO, where R is H, straight, branched or cyclic alkyl up to C20, optionally containing double bonds and/or substituted with halogen, nitro, amino, hydroxy, sulfo, phospho or carboxyl groups (which may be substituted themselves), or aralkyl or aryl optionally substituted as listed for the alkyl and further including alkyl, or R_1 is glycosyl, nucleosyl, lipoyl or R_1 is an L- or D-α amino acid or an oligomer thereof consisting of up to 5 residues R_1 is absent when the amino acid adjacent is a desamino-derivative.

R_2 is
$-NR_{12}R_{13}$, wherein R_{12} and R_{13} are independently H, straight, branched or cyclic alkyl, aralkyl or aryl optionally substituted as defined for R_1 or N-glycosyl or N-lipoyl
$-OR_{14}$, where R_{14} is H, straight, branched or cyclic alkyl, aralkyl or aryl, optionally substituted as defined for R_1
-O-glycosyl, -O-lipoyl or
- an L- or D-α-amino acid or an oligomer thereof consisting of up to 5 residues
or R_2 is absent, when the adjacent amino acid is a decarboxy derivative of cysteine or a homologue thereof or the peptide is in a N-C cyclic form.

with the proviso that:

when X_6 is Cys or R_2 then X_5 is A_{10}, X_4 is A_8-A_9, X_3 is A_6-A_7 and X_2 is A_1-A_2-A_3-A_4-A_5

when X_5 is Cys or R_1 then X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15}, X_8 is A_{16}-A_{17}-A_{18} and A_{11} is absent

when X_4 is Cys or R_1 then X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15} and X_8 is A_{16}-A_{17}-A_{18}

when X_2 is A_1-A_2-A_3-A_4-A_5 then X_8 is not A_{16}

when X_1 is null, X_2 is Cys or R_1, X_3 is A_6-A_7, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15} and X_8 is A_{16} then A_{16} is not D-His.

X_1 is always and only null when X_2 is R_1, Lys or Null

X_2 is always and only null when X_3 is Cys or R_1

X_3 is always and only null when X_6 is Cys or R_2

X_7 is always and only null when X_7 is Cys, R_2 or Null

X_8 is always and only null when X_8 is Cys, R_2 or Null

X_9 is always and only null when X_8 is Cys, R_2 or Null

when X_1 and R_2 are null, X_3 is R_1, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15}, X_8 is R_2 and A_{14} is Ala and A_{15} is absent then R_1 is acetyl and R_2 is NH_2.

The amino acids may be D or L isomers, however generally the peptide will primarily consist of L-amino acids.

In a second aspect the present invention consists in a pharmaceutical composition for use in treating subjects suffering from toxic effects of TNF and/or LPS, the composition comprising a therapeutically effective amount of a peptide of the first aspect of the present invention and a pharmaceutically acceptable sterile carrier.

In a third aspect the present invention consists in a method of treating a subject suffering from the toxic effects of TNF and/or LPS, the method comprising administering to the subject a th rap utically effective amount of the composition of the second asp ct of th present invention.

In a preferred embodiment of the present invention X_1 is H, X_2 is A_1-A_2-A_3-A_4-A_5, X_3 is A_6-A_7, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15}, X_8 is A_{16}-A_{17}-A_{18} and X_9 is OH.

In a further preferred embodiment of the present invention X_1 is null, X_2 is H or Ac, X_3 is A_6-A_7, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15}, X_8 is A_{16}-A_{17}-A_{18} and X_9 is OH or NH_2.

In a further preferred embodiment of the present invention X_1 is H, X_2 is A_1-A_2-A_3-A_4-A_5, X_3 is A_6-A_7, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is OH and X_6, X_7 and X_8 are null.

In a further preferred embodiment of the present invention the peptide is selected from the group consisting of:-

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Ala-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Lys-Asp-Pro-Val-Ala-His-Val-Val-Ala;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Arg-Val-Val-Ala;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Gln-Val-Val-Ala;

Ac-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-NH2;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Ala-Val;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Lys-Val;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val;

Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val;

Pro-Ser-Asp-Lys-Pro-Val-Ala-His;

Pro-Ser-Asp-Lys-Pro-Val;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Val-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala-Asn-Pro-Gln-Ala-Glu-Gly-Gln-Leu;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp;

Ac-Pro-Ser-Asp-Lys-Pro-Val-Ala-NH2;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Asp-Val;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala-Asn-Pro-Gln-Ala-Glu-Gly-Gln-Leu;

Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val;

Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Pro-Sir-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Pro-Val-Ala-His-Val-Val-Ala; and

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Val-His-Val.

The composition and method of the present invention would be expected to be useful as an anti-inflammatory agent in a wide range of disease states including toxic shock, adult respiratory distress syndrome, hypersensitivity pneumonitis, systemic lupus erythromatosis, cystic fibrosis, asthma, bronchitis, drug withdrawal, schistosomiasis, sepsis, rheumatoid arthritis, acquired immuno-deficiency syndrome, multiple sclerosis, leperosy, malaria, systemic vasculitis, bacterial meningitis, cachexia, dermatitis, psoriasis, diabetes, neuropathy associated with infection or autoimmune disease, ischemia/reperfusion injury, encephalitis, Guillame Barre Syndrome, atherosclerosis, chronic fatigue syndrome, TB, other viral and parasitic diseases, OKT3 therapy, and would be expected to be useful in conjunction with radiation therapy, chemotherapy and transplantation, to ameliorate the toxic effects of such treatments or procedures.

As the peptide of the present invention suppresses activation of neutrophils the composition and method of the present invention may also be useful in the treatment of diseases with an underlying element of local, systemic, acute or chronic inflammation. In general, it is believed

the composition and method of the present invention will be useful in treatment of any systemic or local infection leading to inflammation.

The peptides of the present invention may also be administered in cancer therapy in conjunction with cytotoxic drugs which may potentiate the toxic effects of TNFα (Watanabe et al., 1988; Immunopharmacol. Immunotoxicol. 10: 117-127) such as vinblastin, acyclovir, interferon alpha, cyclosporin A, IL-2, actinomycin D, adriamycin, mitomycin C, AZT, cytosine arabinoside, daunororubin, cis-platin, vincristine, 5-flurouracil and bleomycin; in cancer patients undergoing radiation therapy; and in AIDS patients (or others suffering from viral infection such as viral meningitis, hepatitis, herpes, green monkey virus etc.) and in patients receiving immunostimulants such as thymopentin and muramyl peptides or cytokines such as IL-2 and GM-CSF. In this use peptides of the present invention will serve to abrogate the deleterious effects of TNFα

It will be appreciated by those skilled in the art that a number of modifications may be made to the peptide of the present invention without deleteriously effecting the biological activity of the peptide. This may be achieved by various changes, such as insertions, deletions and substitutions (e.g., sulfation, phosphorylation, nitration, halogenation), either conservative or non-conservative (e.g., W-amino acids, desamino acids) in the peptide sequence where such changes do not substantially altering the overall biological activity of the peptide. By conservative substitutions the intended combinations are:-

G, A; V, I, L, M; D, E; N, Q; S, T; K, R, H; F, Y, W, H; and P, Nα-alkylamino acids.

It may also be possible to add various groups to the peptide of the pres nt invention to confer advantages such as increased potency or extended half-life in vivo,

without substantially altering the overall biological activity of the peptide.

The term peptide is to be understood to embrace peptide bond replacements and/or peptide mimetics, i.e. pseudopeptides, as recognised in the art (see for example: Proceedings of the 20th European Peptide Symposium, edt. G. Jung. E. Bayer, pp. 289-336, and references therein), as well as salts and pharmaceutical preparations and/or formulations which render the bioactive peptide(s) particularly suitable for oral, topical, nasal spray, ocular pulmonary, I.V., subcutaneous, as the case may be, delivery. Such salts, formulations, amino acid replacements and pseudopeptide structures may be necessary and desirable to enhance the stability, formulation, deliverability (e.g., slow release, prodrugs), or to improve the economy of production, and they are acceptable, provided they do not negatively affect the required biological activity of the peptide.

Apart from substitutions, three particular forms of peptide mimetic and/or analogue structures of particular relevance when designating bioactive peptides, which have to bind to a receptor while risking the degradation by proteinases and peptidases in the blood, tissues and elsewhere, may be mentioned specifically, illustrated by the following examples: Firstly, the inversion of backbone chiral centres leading to D--amino acid residue structures may, particularly at the N-terminus, lead to enhanced stability for proteolytical degradation while not impairing activity. An example is given in the paper "Tritriated D-ala^1-Peptide T Binding", Smith, C.S. et al, Drug Development Res. 15, pp. 371-379 (1988). Secondly, cyclic structure for stability, such as N to C interchain imides and lactames (Ede et al in Smith and Rivier (Eds) "Peptides: Chemistry and Biology", Escom, Leiden (1991), p268-270), and sometimes also receptor binding may be enhanced by forming cyclic analogues. An

example of this is given in "Confirmationally restricted thymopentin-like compounds", U.S. pat. 4,457,489 (1985), Goldstein, G. et al. Finally, the introduction of ketomethylene, methylsulfide or retroinverse bonds to replace peptide bonds, i.e. the interchange of the CO and NH moieties may both greatly enhance stability and potency. An example of the latter type is given in the paper "Biologically active retroinverso analogues of thymopentin", Sisto A. et al in Rivier, J.E. and Marshall, G.R. (eds.) "Peptides, Chemistry, Structure and Biology", Escom, Leiden (1990), p.722-773.

The peptides of the invention can be synthesized by various methods which are known in principle, namely by chemical coupling methods (cf. Wunsch, E.: "Methoden der organischen Chemie", Volume 15, Band 1 + 2, Synthese von Peptiden, Thieme Verlag, Stuttgart (1974), and Barrany, G.; Merrifield, R.B: "The Peptides", eds. E. Gross, J. Meienhofer., Volume 2, Chapter 1, pp. 1-284, Academic Press (1980)), or by enzymatic coupling methods (cf. Widmer, F., Johansen, J.T., Carlsberg Res. Commun., Volume 44, pp. 37-46 (1979), and Kullmann, W.: "Enzymatic Peptide Synthesis", CRC Press Inc., Boca Raton, Florida (1987), and Widmer, F., Johansen, J.T. in "Synthetic Peptides in Biology and Medicine:, eds., Alitalo, K., Partanen, P., Vatieri, A., pp. 79-86, Elsevier, Amsterdam (1985)), or by a combination of chemical and enzymatic methods if this is advantageous for the process design and economy.

It will be seen that one of the alternatives embraced in the general formula set out above is for a cysteine residue to be positioned at both the amino and carboxy terminals of the peptide. This will enable the cylisation of the peptide by the formation of di-sulphide bond.

It is intended that such modifications to the peptide of the present invention which do not result in a d crease in biological activity are within the scope of the present invention.

As would be recognized by those skilled in the art ther are numerous exampl s to illustrate the ability of anti-idiotypic (anti-Ids) antibodies to an antigen to function like that antigen in its interaction with animal cells and components of cells. Thus, anti-Ids to a peptide hormone antigen can have hormone-like activity and interact specifically with the receptors to the hormone. Conversely, anti-Ids to a receptor can interact specifically with a mediator in the same way as the receptor does. (For a review of these properties see: Gaulton, G.N. and Greane, M.I. 1986. Idiotypic mimicry of biological receptors, Ann. Rev. Immunol. 4, 253-280; Sege, K and Peterson, P.A., 1978. Use of anti-iodiotypic antibodies as cell surface receptor probes. Proc. Natl. Acad. Sci. U.S.A. 75, 2443-2447).

As might be expected from this functional similarity of anti-Id and antigen, anti-Ids bearing the internal image of an antigen can induce immunity to such an antigen. (This nexus is reviewed in Hiernaux, J.R. 1988. Idiotypic vaccines and infectious diseases. Infect. Immun. 56, 1407-1413.)

As will be appreciated by persons skilled in the art from the disclosure of this application it will be possible to produce anti-idiotypic antibodies to the peptide of the present invention which will have similar biological activity. It is intended that such anti-idiotypic antibodies are included within the scope of the present invention.

Accordingly, in a fourth aspect the present invention consists in an anti-idiotypic antibody to the peptide of the first aspect of the present invention, the anti-idiotypic antibody being capable of abrogating TNF and/or LPS toxicity.

The individual specificity of antibodies resides in the structures of the peptide loops making up the Complementary Determining Regions (CDRs) of the variable

domains of the antibodies. Since in general, the amino acid sequences of the CDR peptide loops of an anti-Id are not identical to or even similar to the amino acid sequence of the peptide antigen from which it was originally derived, it follows that peptides whose amino acid sequence is quite dissimilar, in certain contexts can take up a very similar three-dimensional structure. The concept of this type of peptide, termed a "functionally equivalent sequence" or mimotope by Geyson is familiar to those expert in the field. (Geyson, H.M. et al 1987. Strategies for epitope analysis using peptide synthesis. J. Immun. Methods. 102, 259-274).

Moreover, the three-dimensional structure and function of the biologically active peptides can be simulated by other compounds, some not even peptidic in nature, but which mimic the activity of such peptides. This field of science is summarised in a review by Goodman, M. (1990). (Synthesis, spectroscopy and computer simulations in peptide research. Proc. 11th American Peptide Symposium published in Peptides-Chemistry, Structure and Biology pp 3-29. Ed Rivier, J.E. and Marshall, G.R. Publisher ESCOM.)

As will be recognized by those skilled in the art, armed with the disclosure of this application, it will be possible to produce peptide and non-peptide compounds having the same three-dimensional structure as the peptide of the present invention. These "functionally equivalent structures" or "peptide mimics" will react with antibodies raised against the peptide of the present invention and may also be capable of abrogating TNF toxicity. It is intended that such "peptide mimics" are included within the scope of the present invention.

Accordingly, in a fifth aspect the present invention consists in a compound the three-dimensional structure of which is similar as a pharmacophore to the thre - dimensional structure of the peptide of th first aspect

of the present invention, the compound being characterized in that it reacts with antibodies raised against the peptide of the first aspect of the present invention and that the compound is capable of abrogating TNF and/or LPS toxicity.

More detail regarding pharmacophores can be found in Bolin et al. p 150, Polinsky et al. p 287, and Smith et al. p 485 in Smith and Rivier (Eds) "Peptides: Chemistry and Biology", Escom, Leiden (1991).

Detailed Description of the Invention

In order that the nature of the present invention may be more clearly understood, the preferred forms thereof will now be described with reference to the following example and accompanying Figures and Tables in which:

Fig. 1 shows the amino acid sequence of human TNFα ;

Fig. 2: Effect of TNF (□) and TNF+ Peptide 1 (◆) on blood glucose levels in malaria primed mice-Peptide 1 abrogates TNF induced hypoglycaemia in malaria primed mice.

Fig. 3: Effect of Peptide 1 on TNF-induced tumour regression.

Fig. 4: Effect of Peptide 1 (●), peptide 308 (▼), peptide 309 (■), peptide 305 (⊠) and peptide 302 (○) on binding of radiolabelled TNF to TNF receptors on WEH1-164 tumour cells - Peptide 1 does not inhibit binding of TNF to tumour cells.

Fig. 5: Plasma reactive nitrogen intermediate levels in TNF± Peptide 1 treated malaria primed mice - this shows that induction of RNI by TNF is inhibited by treatment with Peptide 1.

Fig. 6 shows the effect on blood glucose levels in mice treated with PBS (□); TNF alone (◆); TNF + Peptide 1 (■) and TNF + Peptide 2 (○).

Fig. 7 shows the effect of Peptide 1 on TNF-induced decrease in blood glucose lev ls in mice administered with 200μg TNF.

Fig. 8 shows the effect of Peptide 1 on TNF-induced decrease in blood glucose levels in ascites tumour-bearing mice.

Fig. 9 shows the effect of Peptide 1 on TNF-induced weight loss in ascites tumour-bearing mice.

Fig. 10 shows the effect of peptides on LPS toxicity in Meth A ascites tumour-bearing mice (10 animals per group scored positive if 7 or more survive);

Fig. 11 shows the effect of peptides on LPS toxicity in Meth A ascites tumour-bearing mice (10 animals per group scored positive if 7 or more survive);

Fig. 12 shows the effect of peptides on TNF toxicity in Meth A ascites tumour-bearing mice (each group contains 20 animals: scored positive if 7 or more survived);

Fig. 13 shows the effect of peptides on TNF toxicity in Meth A ascites tumour-bearing mice (each group contains 20 animals: scored positive if 10 or more survived);

Fig. 14 shows effect of peptides on TNF toxicity in D-galactosamine sensitized mice (each group contains 10 animals: scored positive if 6 or more survive).

Fig. 15 shows the effect of peptides on direct induction of chemiluminescence by TNF on human neutrophils;

Fig. 16 shows inhibition of TNF priming of human neutrophils by Peptide 21;

Fig. 17 shows inhibition of TNF priming of human neutrophils by Peptide 19;

Fig. 18 shows inhibition of LPS stimulation of neutrophils by Peptide 19;

Fig. 19 shows dose-dependent effects of Peptide 9 on TNF-induced chemiluminescence;

Fig. 20 shows effect of peptide 2 on human TNF priming of human neutrophils;

Fig. 21 shows inhibition of LPS-induced chemiluminescence response of human neutrophils by Peptide 21; and

Fig. 22 shows inhibition of TNF priming of human neutrophils by Peptide 21.

Production of Peptides

Synthesis of Peptides Using the FMOC-Strategy

Peptides (1-6, 9-18, 22-25, 27-29, 35, 36, 39, 40 Table 3) were synthesized on the continuous flow system as provided by the Milligen synthesizer Model 9050 using the standard Fmoc-polyamide method of solid phase peptide synthesis (Atherton et al, 1978, J.Chem. Soc. Chem. Commun., 13, 537-539).

For peptides with free carboxyl at the C-terminus, the solid resin used was PepSyn KA which is a polydimethylacrylamide gel on Kieselguhr support with 4-hydroxymethylphenoxyacetic acid as the functionalised linker (Atherton et al., 1975, J.Am.Chem.Soc 97, 6584-6585). The carboxy terminal amino acid was attached to the solid support by a DCC/DMAP-mediated symmetrical-anhydride esterification.

For peptides with carboxamides at the C-terminus, the solid resin used was Fmoc-PepSyn L Am which is analogous polyamides resin with a Rink linker, p-[(R,S)-α[1-(9H-fluoren-9-yl)-methoxyformamido]-2, 4-dimethoxybenzyl]-phenoxyacetic acid (Bernatowicz et al, 1989, Tet.Lett. 30, 4645). The synthesis starts by removing the Fmoc-group with an initial piperidine wash and incorporation of the first amino acid is carried out by the usual peptide coupling procedure.

The Fmoc strategy was also carried out in the stirred cell system in synthesis of peptides (33,34,37,38) where the Wang resin replaced the Pepsyn KA.

All Fmoc-groups during synthesis were removed by 20% piperidine/DMF and peptide bonds were formed either of the following methods except as indicated in Table 1:

1. Pentafluorophenyl active esters. The starting materials are already in the active ester form.
2. Hydroxybenzotriazol esters. These are formed in situ either using Castro's reagent, BOP/NMM/HOBt (Fournier et al, 1989, Int.J.Peptide Protein Res., 33, 133-139) or

using Knorr's reagent, HBTU/NMM/HOBt (Knorr et al, 1989, Tet.Lett., 30, 1927).

Side chain protection chosen for the amino acids was removed concomitantly during cleavage with the exception of Acm on cysteine which was left on after synthesis. Intramolecular disulphide bridges where needed are then formed by treating the Acm protected peptide with iodine/methanol at high dilution.

TABLE 1

Amino Acid	Protecting Group	Coupling Method
Arg	Pmc	HOBt or OPfp
Asp	OBut	HOBt or OPfp
Cys	Acm	HOBt or OPfp
Glu	OBut	HOBt or OPfp
His	Boc or Trt	HOBt or OPfp
Lys	But	HOBt or OPfp
Ser	But	HOBt only
Thr	But	HOBt only
Tyr	But	HOBt or OPfp
Asn	none	OPfp only
Gln	none	OPfp only

Cleavage Conditions

Peptides were cleaved from the PepSyn KA and PepSyn K Am using 5% water and 95% TFA where Arg(Pmc) is not present. Where Arg(Pmc) is present a mixture of 5% thioanisole in TFA is used. The cleavage typically took 3 h at room temperature with stirring. Thioanisole was removed by washing with ether or ethyl acetate and the peptide was extracted into an aqueous fraction. Up to 30% acetonitrile was used in some cases to aid dissolution. Lyophilization of the aqueous/acetonitrile extract gave the crude peptide.

Peptides from the Wang resin were cleaved using 5% phenol, 5% ethanedithiol and 90% TFA for 16 h at ambient temperature with stirring. Thioanisol was removed by

washing with ether or ethyl acetate and the peptide was extracted into an aqueous fraction. Up to 30% acetonitrile was used in some cases to aid dissolution. Lyophilization of the aqueous/acetonitrile extract gave the crude peptide.

Peptides from the Wang resin were cleaved using 5% phenol, 5% ethanedithiol and 90% TFA for 16 h at ambient temperature with stirring.

Purification

Crude peptide is purified by reverse phase chromatography using either a C4 or C18 column and the Buffer system: Buffer A - 0.1% aqueous TFA, Buffer B - 80% Acetonitrile and 20% A.

N-Terminal Acetylation

The peptide resin obtained after the synthesis (with Fmoc removed in the usual manner was) placed in a 0.3 MDMF solution of 10 equivalents of Ac-OHSu for 60 minutes. The resin was filtered, washed with DMF, CH2C12, ether and used in the next step.

Cyclization

The purified and lyophilized bis-S-(acetamidomethyl) cysteine peptide (100-400 mg) was dissolved in 5 mls of methanol containing 1 ml of acetic acid. This was added dropwise to a 1 litre methanol solution containing 1 g of iodine.

After 2 h reaction, the excess iodine was removed by addition of a dilute sodium thiosulfate solution until the colour turns to a pale yellow, methanol was removed in vacuo at room temperature and the concentrated solution was finally completely decolourised with dropwise addition of sodium thiosulfate and applied immediately onto a preparatively reverse phase chromatography column.

Synthesis of Peptides using the Boc-Strategy

Syntheses of th se p ptides were carried out on the ABI 430A instrument using polystyrene bas d resins. For peptide with C-terminal acids, the appropriate Merrified

resin Boc-amino acid-O-resin or the 100-200 mesh PAM resin is used (7, 8, 19-21, 26, 31). Peptides with C-terminal amides are synthesized on MBHA resins (32, 33).

Couplings of Boc-amino acids (Table 2) were carried out either using symmetrical anhydride method or a HOBt ester method mediated by DCC or HTBU.

TABLE 2

Amino Acid	Protecting Group	Coupling Method
Arg	Tos	HOBt or S.A.
Asp	Cxl,OBzl	HOBt or S.A.
Cys	4-MeBzl	HOBt or S.A.
Glu	Cxl	HOBt or S.A.
His	Dnp, Bom	HOBt or S.A.
Lys	2-ClZ	HOBt or S.A.
Ser	Bzl	HOBt or S.A.
Thr	Bzl	HOBt or S.A.
Tyr	Br-Z	HOBt or S.A.
Asn	Xan	HOBt or S.A.
Gln	none	HOBt only

Cleavage

Peptides were cleaved in HF with p-cresol or anisole as scavenger for up to 90 min. For His with Dnp protection, the resin required pre-treatment with mercaptoethanol:DIPEA:DMF (2:1:7), for 30 min. After removal of scavengers by ether wash, the crude peptide is extracted into 30% acetonitrile in water.

N-Terminal Acetylation

Acetylation was achieved by treating the deblocked resin with acetic anhydride in DMF solution.

TABLE 3

No	hTNF	Sequence
1	1-18	VAL ARG SER SER SER ARG THR PRO SER ASP LYS PRO VAL ALA HIS VAL VAL ALA
2	6-18	ARG THR PRO SER ASP LYS PRO VAL ALA HIS VAL VAL ALA

3	2-15	ART SER SER SER ARG THR PRO SER ASP LYS PRO VAL ALA HIS
4	1-26	VAL ARG SER SER SER ARG THR PRO SER ASP LYS PRO VAL ALA HIS VAL VAL ALA ASN PRO GLN ALA GLU GLY GLN LEU
5	10-18	ASP LYS PRO VAL ALA HIS VAL VAL ALA
6	15-22	HIS VAL VAL ALA ASN PRO GLN ALA
7	6-16	ARG THR PRO SER ASP LYS PRO VAL ALA HIS VAL
8	6-17	ARG THR PRO SER ASP LYS PRO VAL ALA HIS VAL VAL
9	8-16	PRO SER ASP LYS PRO VAL ALA HIS VAL
10	8-15	PRO SER ASP LYS PRO VAL ALA HIS
11	8-15	PRO SER ASP LYS PRO VAL ALA
12	8-13	PRO SER ASP LYS PRO VAL
13	7-18	THR PRO SER ASP LYS PRO VAL ALA HIS VAL VAL ALA
14	8-18	PRO SER ASP LYS PRO VAL ALA HIS VAL VAL ALA
15	9-18	SER ASP LYS PRO VAL ALA HIS VAL VAL ALA
16	11-18	LYS PRO VAL ALA HIS VAL VAL ALA
17	12-18	PRO VAL ALA HIS VAL VAL ALA
18	12-18	Ac PRO VAL ALA HIS VAL VAL ALA NH2
19	6-18	ARG THR PRO SER ALA LYS PRO VAL ALA HIS VAL VAL ALA
	Ala(10)	
20	6-18	ARG THR PRO SER ASP ALA PRO VAL ALA HIS VAL VAL ALA
	Ala(11)	
21	6-18	ARG THR PRO SER LYS ASP PRO VAL ALA HIS VAL VAL ALA
	Lys(10)	
	Asp(11)	
22	1-18	VAL ARG SER SER SER ARG THR PRO SER ASP LYS PRO VAL ALA ARG VAL VAL ALA
	Arg(15)	

	23	1-18	VAL ARG SER SER SER ARG THR PRO SER ASP
		GLN(15)	LYS PRO VAL ALA GLN VAL VAL ALA
	24	1-18	VAL ARG SER SER SER ARG THR PRO SER ASP
		Leu(14)	LYS PRO VAL LEU HIS VAL VAL ALA
5	25	1-18	VAL ARG SER SER SER ARG THR PRO SER ASP
			LYS PRO VAL VAL HIS VAL VAL ALA
		Val(14)	
	26	6-26	ARG THR PRO SER ASP LYS PRO VAL ALA HIS
			VAL VAL ALA ASN PRO GLN ALA GLU GLY GLN
10			LEU
	27	1-16	VAL ARG SER SER SER ARG THR PRO SER ASP
			LYS PRO VAL ALA HIS VAL
	28	1-10	VAL ARG SER SER SER ARG THR PRO SER ASP
	29	8-14	Ac PRO SER ASP LYS PRO VAL ALA NH2
15	30	6-16	Ac ARG THR PRO SER ASP LYS PRO VAL ALA
			HIS VAL NH2
	31	6-16	ARG THR PRO SER ASP LYS PRO VAL VAL HIS
			VAL
		Val(14)	
20	32	6-16	ARG THR PRO SER ASP LYS PRO VAL ALA HIS
			ALA
		ALA(16)	
	33	6-16	ARG THR PRO SER ASP LYS PRO VAL ALA ALA
			VAL
25		ALA(15)	
	34	6-16	ART THR PRO SER ASP LYS PRO VAL ALA LYS
			VAL
		LYS(15)	
	35	6-16	ARG THR PRO SER ASP LYS PRO VAL ALA ASP
30			VAL
		ASP(15)	
	36	6-16	ARG THR PRO SER ASP LYS PRO VAL ALA D-HIS
			VAL
		D-HIS(15)	
35	275	111-120	ALA LYS PRO TRP TYR GLU PRO ILE TYR LEU

302	43-48	LEU ARG ASP ASN GLN LEU VAL VAL PRO SER SLU GLY LEU TYR LEU ILE
303	94-109	LEU SER ALA ILE LYS SER PRO LYS GLN ARG GLU THR PRO GLU GLY ALA
304	63-83	LEU PHE LYS GLY GLN GLY CYS PRO SER THR HIS VAL LEU LEU THR HIS THR ILE SER ARG ILE
305	132-150	LEU SER ALA GLU ILE ASN ARG PRO ASP TYR LEU ASP PHE ALA GLU SER GLY GLN VAL
306	13-26	VAL ALA HIS VAL VAL ALA ASN PRO GLN ALA GLU GLY GLN LEU
307	22-40	ALA GLU GLY GLN LEU GLN TRP LEU ASN ARG ARG ALA ASN ALA LEU LEU ALA ASN GLY
308	54-68	GLY LEU TYR LEU ILE TYR SER SLN VAL LEU PHE LYS GLY GLN GLY
309	73-94	HIS VAL LEU LEU THR HIS THR ILE SER ARG ILE ALA VAL SER TYR GLN THR LYS VAL ASN LEU LEU
323	79-89	THR ILE SER ARG ILE ALA VAL SER TYR GLN THR
347	132-157	LEU SER ALA GLU ILE ASN ARG PRO ASP TYR LEU ASP PHE ALA GLU SER GLY GLN VAL TYR PHE GLY ILE ILE ALA LEU

Endothelial Cell Clotting Assays

Endothelial cell procoagulant activity (PCA) induction by TNFα was determined using bovine aortic endothelial cells (BAE) according to the procedure of Bevilacqua et al., 1986 PNAS 83, 4522 with the following modifications: BAE cells were propagated in McCoys 5A medium supplemented with 10% FCS, penicillin, streptomycin and L-gutamine in standard tissue culture flasks and 24-well dishes. TNFα treatment of culture (3μg/ml) was for 4 hours at 37°C in the presence of growth medium after which the cells were wash d and scrape-harvested before being frozen, thawed and sonicated. Total cellular PCA was determined in a standard one-stage clotting assay

using normal donor platelet poor plasma to which 100µl of $CaCl_2$ and 100µl of cell lystate was added. Statistical significance was determined by unpaired t-test.

Neutrophil Activation Studies

In these experiments, neutrophils were prepared from blood of healthy volunteers by the rapid single step method (Kowanko and Ferrante 1987 Immunol 62, 149). To 100µl of 5 x 10^6 neutrophils/ml was added 100µl of either 0, 10, 100µg of peptide/ml and 800µl of lucigenin (100µg). The tubes were immediately placed into a light proof chamber (with a 37°C water jacket incubator) of a luminometer (model 1250; LKB Instruments, Wallac, Turku, Finaldn). The resultant light output (in millivolts was recorded). The results are recorded as the maximal rate of chemiluminescence production.

Effects of peptides on neutrophil chemiluminescence induced by either TNF or LPS: Neutrophils of 96-99% purity and)99% viability were prepared from blood of normal healthy volunteers by centrifugation (400g for 30 min) through Hypaque-Ficoll medium of density 1.114. Following centrifugation the neutrophils formed a single band above the erythrocytes and 1 cm below the mononuclear leukocyte band. These were carefully recovered and washed in medium 199. To assess the lucigenin-dependent chemiluminescence response 100ul of 5 x 10^6 neutrophils/ml was added 100ul of either 0,1,10,100ug of peptide/ml and TNF or LPS and 800ul of lucigenin (100ug). The tubes were immediately placed into a light proof chamber with a 37°C water jacket incubator of a luminometer. The resultant light output (in millivolts) was recorded. The results are recorded as the maximal of chemiluminescence production. In experiments which examined the ability of the peptides to prime for the response to fMLP, 100ul of 5 x 10^5 neutrophils /ml preincubated in peptide and LPS or TNF for 20 mins was

added to 100ul of diluent or fMLP (5×10^{-6}M) before the addition of 700ul of lucigenin (100ug). The chemiluminescence was measured as above. Neutrophils from at least three individuals were used in triplicate determinations of anti-TNF or LPS activity. Results were deemed positive if at least 50% inhibition of chemiluminescence was obtained in at least two thirds of cases.

WEH1-164 Cytoxicity

Bioassay of recombinant TNF activity was performed according to the method described by Espevik and Nissen-Meyer. (Espevik and Nissen-Meyer 1986 J. Immunol. Methods 95 99-105)

Tumour Regression Experiments

Subcutaneous tumours were induced by the injection of approximately 5×10^5 WEH1-164 cells. This produced tumours of diameters of 10 to 15mm approximately 14 days later. Mice were injected i.p. with recombinant human TNF (10μg and 20μg) and peptide (1mg) for four consecutive days. Control groups received injections of PBS. Tumour size was measured daily throughout the course of the experiment. Statistical significance of the results was determined by unpaired Student T-test.

Radioreceptor assays

WEH1-164 cells grown to confluency were scrape harvested and washed once with 1% bovine serum albumin in Hanks balanced salt solution (HBSS, Gibco) and used at 2×10^6 cells pre assay sample. For the radioreceptor assay, the cells were incubated with varying amounts of either unlabelled TNFα(1-10^4 ng per assay sample) or peptide (0-10^5 ng per assay sample) and ^{125}I-TNF (50,000cpm) for 3 hours at 37°C in a shaking water bath. At the completion of the incubation 1ml of HBSS/BSA was added to th WEH1-164 cells, the cells spun and the bound ^{125}I in the cell pellet counted. Specific binding

was calculated from total binding minus non-specific binding of triplicate assay tubes. 100% specific binding corresponded to 1500 cpm.

In Vivo Studies of TNF Toxicity

Mice were administered with either TNF (200μg), Peptide 1 (10mg) and TNF (200μg)+Peptide 1 (10mg) via intravenous injection. Blood glucose levels and appearance of the animals was evaluated at 15, 30, 60, 120, 180 minutes after injection. Appearance parameters which were evaluated included ruffling of fur, touch sensitivity, presence of eye exudate, light sensitivity and diarrhoea.

Infection of mice with malaria parasites and treatment with TNF+ Peptide 1

All the mice used were male, CBA/CaH stain and 6-8 weeks old. P. vinkei vinkei (Strain V52, from F.E.G. Cox, London) has undergone several serial passages in CBA mice, after storage in liquid nitrogen, before use in these experiments. Infections were initiated by intraperitoneal injection of 10^6 parasitized erythrocytes. Mice were treated with TNF(7μg) ± peptide (8.3 mg) administered iv.

Assays for blood glucose

Nonfasting blood glucose levels were determined on a Beckman Glucose Analyzer 2 (Beckman Instruments) or on a Exectech blood glucose sensor (Clifford Hallam Pty. Ltd).

Reactive Nitrogen Intermediates (RNI)

RNI levels in blood were determined by the method of Rockett et al (1991) in-vivo induction of TNF, LT and IL-1 implies a role for nitric oxide in cytokine-induced malarial cell-mediated immunity and pathology. J. Immunol. in press.

TNF and LPS Lethality Experiments: balb/C or balbC x swiss F1 mice carrying Meth A ascites tumours elicited by prior I.P. inoculation of 0.5μl pristane 7 days before I.P. injection of tumour cells. Nine to ten days after

inoculation with the tumour cells 25 ug of human recombinant TNF was subcutaneously administered and a short time later 1mg of either test peptide, bovine serum albumen, phosphate buffered saline or neutralizing anti-TNF MAb 47 was administered at a separate subcutaneous site. The number of surviving animals was then observed at 18 hours and 24 hours post TNF treatment. In experiments which assessed the effects of 1-related peptides on on LPS lethality the mice were administered 500ug E.coli LPS and peptide or other treatment in a similar manner. In LPS experiments polymyxin B, an LPS inhibitor, replaced MAb 47 as a positive control. The number of animals surviving was assessed at intervals up to 64 hours after LPS challenge.

Experiments in D-galactosamine sensitized mice: Female Bablb/C mice were co-injected intraperitoneally with 16 mg D-galactosamine and 2ug human recombinant TNF. The mice were then injected subcutaneously with either test peptide, phosphate buffered saline or neutralizing anti-TNF monoclonal antibody 47. The number of surviving animals was assessed at intervals up to 48 hours after TNF challenge.

RESULTS

The results obtained with each of the peptides are summarised in Table 4. A single * indicates heightened activity in that test whilst a double ** indicates activity at low concentrations of peptide but not high concentrations.

TABLE 4

PEPTIDE	IN VIVO TNF TOXICITY METH A	IN VIVO TNF TOXICITY D-GAL	IN VIVO LPS TOXICITY METH A	IN VITRO NEUTROPHIL DIRECT	IN VITRO NEUTROPHIL TNF PRIMING	IN VITRO NEUTROPHIL LPS DIRECT	IN VITRO NEUTROPHIL LPS PRIMING
1	+	+	+	+	+	+	+
2	+*	+	+	+*			
8	-		-	+			
9	-		-	+**			
10	+*	-	-	+			
11	-			-			
12	+			-			
16	-			-			
17	-		+	-			
13	-		-	+			
14	-		+	+			
15	-		-	-			
18	-	-					
19	+		+	+	+	+	+
20	-		-	-			
21	+*		+	+	+	+	+
22		+	+	+	+		
23	+	+	+	+			
24	-		-	-			
25	+/-		-	+			
26	-		-	+			
4	-			+			
5	-		-	+			
6	-			-			
3	-						
28	+	-	+				
29	-	-	+				
30	+*	+	+				
31	+	+	-				
32	-		-				
33	-		+*				
34	-		+*				
36	-		-				
35	+		+				
27	-		-				
7	-		+	+*			

TNF administered at a dose of 200μg was found to b toxic in mice according to the parameters studied. In particular, blood glucose levels had fallen by 120 minutes (Fig 7) Peptide 1 alone in 2 of the 3 mice studied did not reduce blood glucose levels. Mouse 1 in this group recovered normal blood glucose levels within by 180 minutes. Mice in the group treated with a combination of TNF and Peptide 1 showed no reduction in blood glucose levels at 120 min and a small decrease at 180 min.

As shown in Fig. 6, 10μg of Peptide 2 given to mice treated with 200μg of recombinant human TNF abrogated TNF toxicity as indicated by the inhibition of blood glucose changes evident in mice treated with TNF alone.

When general appearance of treated mice was considered it was noted that all 3 TNF only treated mice had ruffled fur, touch sensitivity and light sensitivity. One mouse in this group also had diarrhoea. Mice treated with Peptide 1 alone showed only slight touch sensitivity with one mouse showing slight ruffling of the fur at 180 mins. Mice treated with a combination of TNF and Peptide 1 showed ruffling of the fur and slight touch sensitivity at 180 mins but failed to show either light sensitivity or onset of diarrhoea. In addition, Peptide 1 and related peptides prevented death in acute models of TNF tethality (Figs. 12 & 13).

Peptide 1 failed to either activate the respiratory burst of human neutrophils (Table 5) or to induce procoagulant activity on bovine aortic endothelial cells, and hence is free of these negative aspects of TNF activity in acute or chronic inflammation. However, Peptide 1 and related peptides inhibited both the TNF and LPS-induced respiratory burst of human neutrophils (Figs. 15, 19, 18, 21). Further, several peptides inhibited priming of the neutrophil response to a bacterially-derived peptide EMLP (Figs. 16, 17, 20, 22).

TABLE 5

Peptide	Concentration ug/10^6 cells)				
	0	1	10	100	500
275	1.02	0.99	0.69	0.43	0.80
1	0.34	0.93	0.74	0.55	1.10
302	0.37	0.15	0.18	0.29	
303	0.37	0.22	0.17	0.22	
304	0.37	0.18	0.43	2.56	2.76
305	0.37	0.27	0.36	0.24	
306	0.37	0.27	0.35	0.23	
307	0.37	0.35	0.37	0.42	
323	0.37	0.23	0.17	0.47	
308	0.37	0.91	1.80	49.52	
309	0.37	0.38	0.98	13.44	

Results are expressed as mV of lucigenin dependent chemiluminescence and represent peak of response i.e. the maximal cell activity attained.

The results shown in Fig. 3 clearly show one of the desirable effects of TNFα, i.e. tumour regression, is unaffected by Peptide 1. Further, Peptide 1 does not inhibit binding of TNF to tumour cell receptors (Fig 4). Table 6 indicates that Peptide 1 is devoid of intrinsic anti-tumour activity. The ability of Peptide 1 to prevent high plasma RNI levels in TNFα treated malaria primed mice is also strongly indicative of the therapeutic usefulness of this peptide (Fig 5). Peptide 1 also inhibits the TNF-induced decrease in blood glucose levels evident in mice treated with TNF alone (Fig 2). Further in the experiments involving mice infected with malaria parasites; of the three mice treated with TNFα alone one died and the other two were moribund. In contrast in the

group of three mice treated with TNFα and P ptide 1 all survived and none were moribund. This v ry marked result also strongly indicates the potential usefulness of this peptide as a therapeutic.

Peptide 1 inhibits not only the TNF-induced hypoglycaemia in sensitized mice but also in ascites tumour-bearing mice (Fig 8). Further, tumour-bearing mice treated with TNF + Peptide 1 fail to develop the cachexia or weight loss associated with TNF treatment (Fig 9).

As will be seen from the above information the peptide of the present invention are capable of abrogating TNF and/or LPS toxicity in vivo and neutrophil activation by LPS or TNF in vitro. This peptide has utility in the treatment of numerous disease states which are due to the deleterious effects of TNF and/or LPS.

TABLE 6

In vitro cytotoxicity of TNF and synthetic TNF peptides on WEHI 164 fibrosarcoma cells

TNF/PEPTIDE	% VIABLE CELLS*
TNF#	26.6
275+	100
1	100
302	48.7
304	100
305	72.7
306	100
307	100
308	42.2
309	92.8

* %Viability was determined by comparison with untreated control cells. Results shown are the means of quadruplicate determinations.

\# TNF was at 50 units per culture which is equivalent to 3ug (12ug/ml)

\+ Each peptide was tested at 50ug/culture (200ug/ml)

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be mad to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

CLAIMS:-

1. A linear or cyclic peptide of the general formula:-

X_1-X_2-X_3-X_4-X_5-X_6-X_7-X_8-X_9

in which

X_1 is null, Cys or R_1

X_2 is null, Cys, R_1 or A_1-A_2-A_3-A_4-A_5

in which A_1 is Val or Ile or Leu or Met or His

A_2 is Arg or Cys or His

A_3 is Ser or Thr or Ala

A_4 is Ser or Thr or Ala

A_5 is Ser or Thr or Ala

X_3 is Cys, R_1 or A_6-A_7

in which A_6 is Arg or Cys or His or Absent

A_7 is Thr or Ser or Ala

X_4 is Cys, R_1 or A_8-A_9

in which A_8 is Pro or an Nα-alkylamino acid

A_9 is Ser or Thr or Ala

X_5 is Cys, R_1 or A_{10}

in which A_{10} is Asp or Ala or Cys or Glu or Gly or Arg or His

X_6 is Cys, R_2 or A_{11}-A_{12}-A_{13}

in which A_{11} is absent or Cys or Arg or His or Asp or Glu

A_{12} is Pro or an Nα-alkylamino acid

A_{13} is Val or Ile or Phe or Tyr or Trp or His or Leu or His or Met

X_7 is null, Cys, R_2 or A_{14}-A_{15}

in which A_{14} is Ala or Val or Gly or Ile or Phe or Trp or Tyr or Leu or His or Met

A_{15} is absent or His or Arg or Glu or Asn or Ala or Lys or Asp or Phe or Tyr or Tap or Glu or Gln or Ser or Thr or Gly

X_8 is null, Cys, R_2, A_{16}, A_{16}-A_{17}, A_{16}-A_{17}-A_{18} or A_{16}-A_{17}-A_{18}-A_{19}-A_{20}-A_{21}-A_{22}-A_{23}-A_{24}-A_{25}-A_{26}

in which A_{16} is Val or Ile or Leu or Met or His
A_{17} is Val or Ile or Leu or Met or His
A_{18} is Ala or Gly
A_{19} is Asp or Glu
A_{20} is Pro or an Nα-alkylamino acid
A_{21} is Gln or Asn
A_{22} is Ala or Gly
A_{23} is Glu or Asp
A_{24} is Gly or Aln
A_{25} is Gln or Asn
A_{26} is Leu or Ile or Val or Met or His

X_9 is null, Cys or R_2

R_1 is R-CO, where R is H, straight, branched or cyclic alkyl up to C20, optionally containing double bonds and/or substituted with halogen, nitro, amino, hydroxy, sulfo, phospho or carboxyl groups (which may be substituted themselves), or aralkyl or aryl optionally substituted as listed for the alkyl and further including alkyl, or R_1 is glycosyl, nucleosyl, lipoyl or R_1 is an L- or D-α amino acid or oligomers thereof consisting of up to 5 residues R_1 is absent when the amino acid adjacent is an unsubstituted desamino-derivative.

R_2 is
$-NR_{12}R_{13}$, wherein R_{12} and R_{13} are independently H, straight, branched or cyclic alkyl, aralkyl or aryl optionally substituted as defined for R_1 or N-glycosyl or N-lipoyl
$-OR_{14}$, where R_{14} is H, straight, branched or cyclic alkyl, aralkyl or aryl, optionally substituted as defined for R_1
-O-glycosyl, -O-lipoyl or
- an L- or D-α-amino acid or a oligamu thereof consisting of up to 5 residues
or R_2 is absent, when the adjacent amino acid is a decarboxy derivative of cysteine or a homologue thereof or the peptide in a N-C cyclic form.

with the proviso that:

when X_6 is Cys or R_2 th n X_5 is A_{10}, X_4 is A_8-A_9, X_3 is A_6-A_7 and X_2 is A_1-A_2-A_3-A_4-A_5

when X_5 is Cys or R_1 then X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15}, X_8 is A_{16}-A_{17}-A_{18} and A_{11} is absent

when X_4 is Cys or R_1 then X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15} and X_8 is A_{16}-A_{17}-A_{18}

when X_2 is A_1-A_2-A_3-A_4-A_5 then X_8 is not A_{16}

when X_1 is null, X_2 is Cys or R_1, X_3 is A_6-A_7, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15} and X_8 is A_{16} then A_{16} is not D-His.

X_1 is always and only null when X_2 is R_1, Lys or Null

X_2 is always and only null when X_3 is Cys or R_1

X_3 is always and only null when X_6 is Cys or R_2

X_7 is always and only null when X_7 is Cys, R_2 or Null

X_8 is always and only null when X_8 is Cys, R_2 or Null

X_9 is always and only null when X_8 is Cys, R_2 or Null

when X_1 and R_2 are null, X_3 is R_1, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15}, X_8 is R_2 and A_{14} is Ala and A_{15} is absent then R_1 is acetyl and R_2 is NH_2.

2. A linear or cyclic peptide as claimed in claim 1 in which:-

X_1 is H, X_2 is A_1-A_2-A_3-A_4-A_5, X_3 is A_6-A_7, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15}, X_8 is A_{16}-A_{17}-A_{18} and X_9 is OH.

3. A linear or cyclic peptide as claimed in claim 1 in which:-

X_1 is null, X_2 is H or Ac, X_3 is A_6-A_7, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is A_{11}-A_{12}-A_{13}, X_7 is A_{14}-A_{15}, X_8 is A_{16}-A_{17}-A_{18} and X_9 is OH or NH_2.

4. A linear or cyclic peptide as claimed in claim 1 in which:-

X_1 is H, X_2 is A_1-A_2-A_3-A_4-A_5, X_3 is A_6-A_7, X_4 is A_8-A_9, X_5 is A_{10}, X_6 is OH and X_6, X_7 and X_8 are null.

5. A linear or cyclic peptide as claimed in claim 1 in which the peptide is selected from the group consisting of:-

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Ala-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Lys-Asp-Pro-Val-Ala-His-Val-Val-Ala;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Arg-Val-Val-Ala;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Gln-Val-Val-Ala;

Ac-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-NH2;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Ala-Val;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Lys-Val;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val;

Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val;

Pro-Ser-Asp-Lys-Pro-Val-Ala-His;

Pro-Ser-Asp-Lys-Pro-Val;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Val-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala-Asn-Pro-Gln-Ala-Glu-Gly-Gln-Leu;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp;

Ac-Pro-Ser-Asp-Lys-Pro-Val-Ala-NH2;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Asp-Val;

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala-Asn-Pro-Gln-Ala-Glu-Gly-Gln-Leu;

Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;

Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val;

Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;
Pro-Sir-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;
Pro-Val-Ala-His-Val-Val-Ala; and
Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Val-His-Val.

6. A peptide as claimed in claim 5 in which the peptide is

Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;
Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-His-Val-Val-Ala;
Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp;
Arg-Thr-Pro-Ser-Ala-Lys-Pro-Val-Ala-His-Fal-Val-Ala;
Arg-Thr-Pro-Ser-Lys-Asp-Pro-Val-Ala-His-Val-Val-Ala;
Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Arg-Val-Val-Ala;
Val-Arg-Ser-Ser-Ser-Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Gln-Val-Val-Ala; or
Arg-Thr-Pro-Ser-Asp-Lys-Pro-Val-Ala-Asp-Val.

7. A pharmaceutical composition for use in treating subjects suffering from acute or chronic inflammation, the composition comprising a therapeutically effective amount of a peptide as claimed in any one of claims 1 to 6 and a pharmaceutically acceptable sterile carrier.

8. A composition as claimed in claim 7 in which the composition is for administration topically, as a nasal spray, ocularly, intraveneously, intraperitoneally, intramuscularly, subcutaneously or for oral delivery.

9. A composition as claimed in claims 7 or 8 in which the composition provides slow release of the active peptide.

10. A method of treating a subject suffering from acute or chronic inflammation, the method comprising administering to the subject the composition as claimed in any one of claims 7 to 9.

11. A method as claimed in claim 10 in which the subject is suffering from toxic shock, adult respiratory distr ss

syndrome, hypersensitivity pneumonitis, systemic lupus erythromatosis, cystic fibrosis, asthma, bronchitis, drug withdrawal, schistosomiasis, sepsis, rheumatoid arthritis, acquired immuno-deficiency syndrome, multiple sclerosis, leperosy, malaria, systemic vasculitis, bacterial meningitis, cachexia, dermatitis, psoriasis, diabetes, neuropathy associated with infection or autoimmune disease, ischemia/reperfusion injury, encephalitis, Guillame Barre Syndrome, atherosclerosis, chronic fatigue syndrome, TB, other viral and parasitic diseases and OKT3 therapy.

12. A method of ameliorating or reducing the adverse side effects in a subject receiving cytotoxic drugs, cytokines, immunopotentiating agents, radiation therapy and/or chemotherapy comprising administering to the subject the composition as claimed in any one of claims 7 to 9.

13. An anti-idiotypic antibody to the peptide as claimed in any one of claims 1 to 6, the anti-idiotypic antibody being characterised in that it is capable of abrogating TNF and/or LPS toxicity.

14. A compound the three dimensional structure of which is similar as a pharmacophore to the three dimensional structure of the peptide as claimed in any one of claims 1 to 6, the compound being characterised in that it binds to one or more antibodies raised against the peptides as claimed in any one of claims 1 to 6 and that the compound is capable of abrogating TNF and/or LPS toxicity.

FIG. 1

VRSSSRTPSD10**KPVAHVVA**NP20QAEGQLQWLN30RRA

NALLANG40VELRDNQLVV50PSEGLYLIYS60QVLFKGQGCP70STHVLL

THTI80SRIAVSYQTK90VNLLSAIKSP100CQRETREGAE110AKPWYEPI

YL120GGVFQLEKGD130RLSAEINRPD140YLDFAESGQV150YFGIIAL157

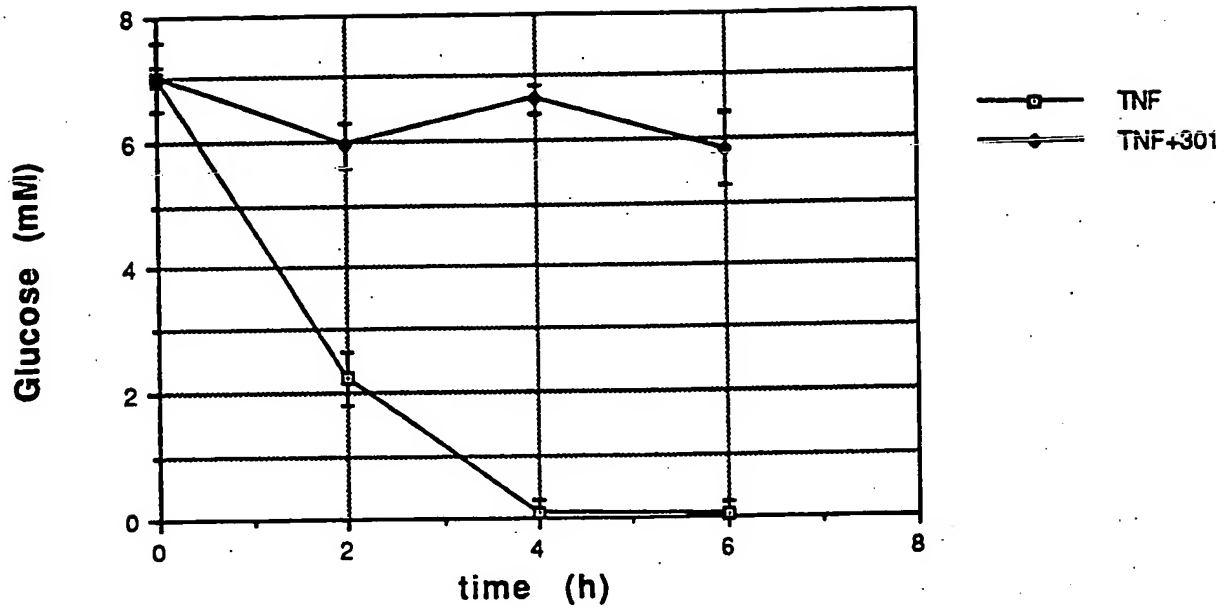


Fig 2

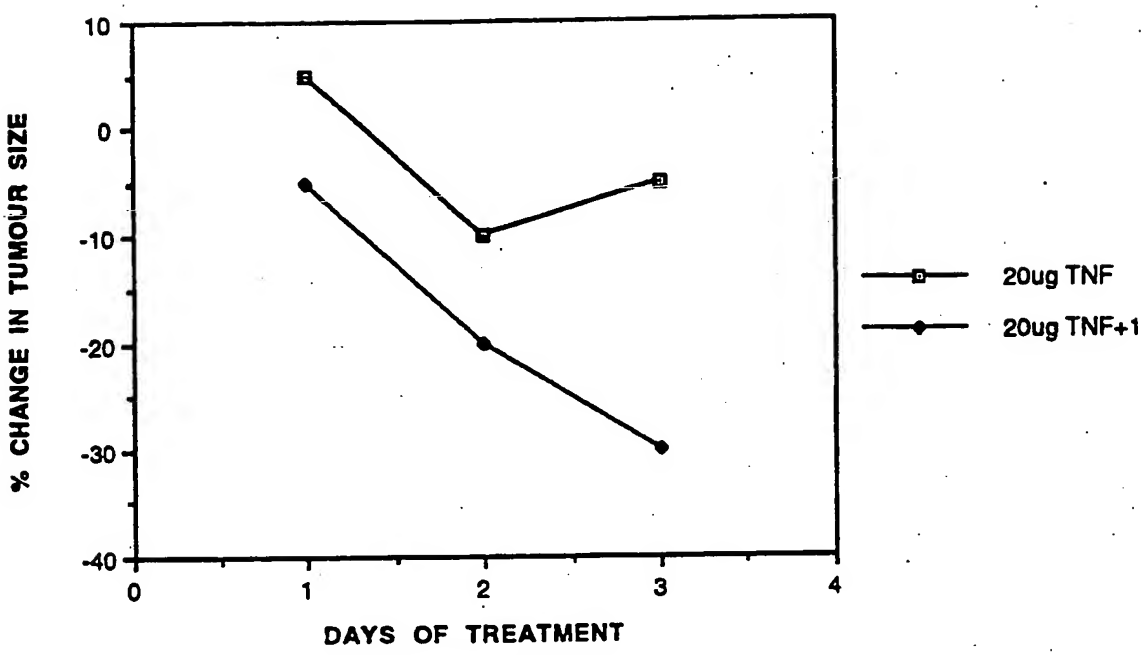
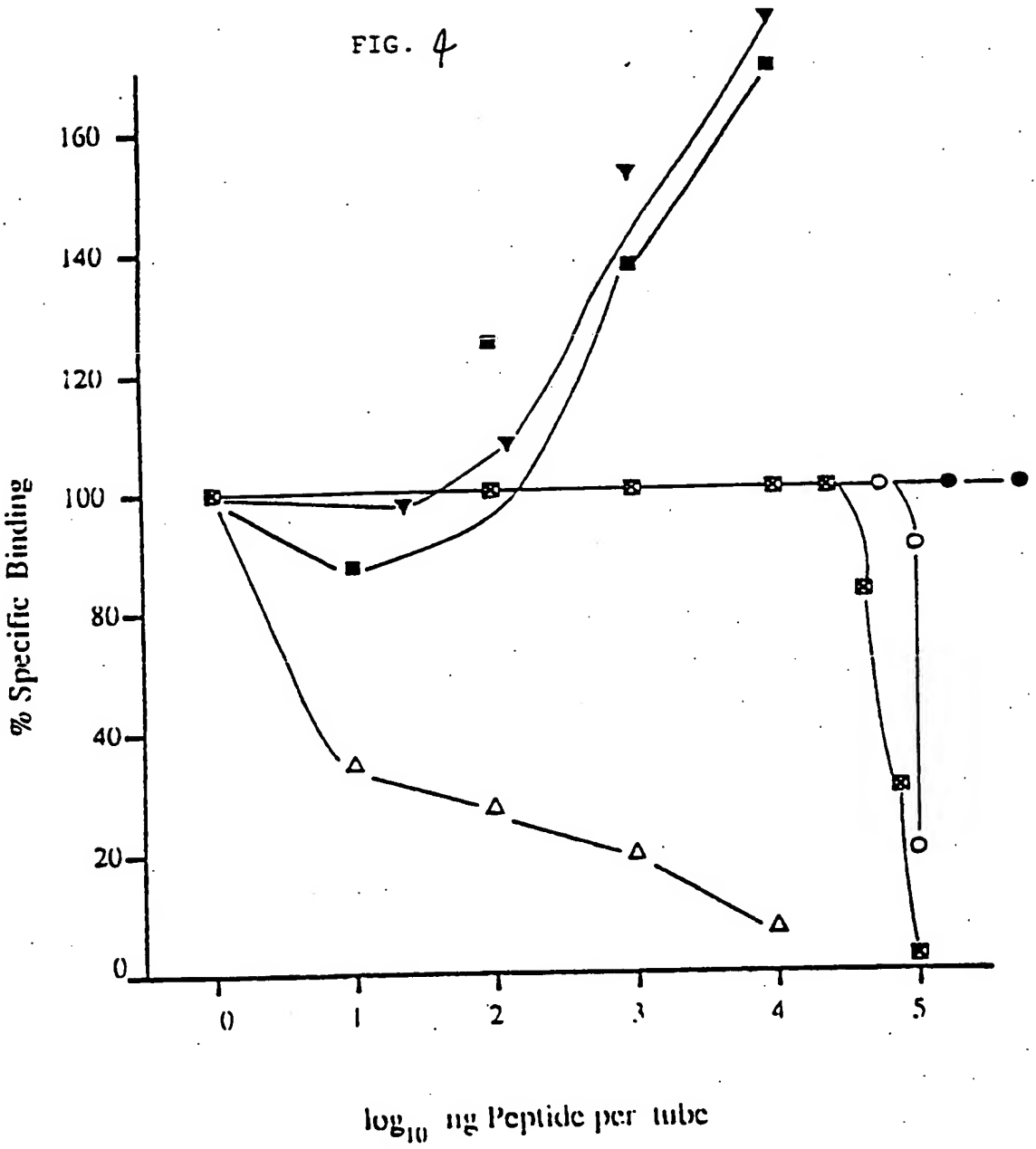

10
0
-10
-20
-30
-40
% CHANGE IN TUMOUR SIZE
0
1
2
3
4
DAYS OF TREATMENT
20ug TNF
20ug TNF+1

Fig 3

4/22

FIG. 4


160
140
120
100
80
40
20
0
% Specific Binding
0
1
2
3
4
5
log10 ng Peptide per tube

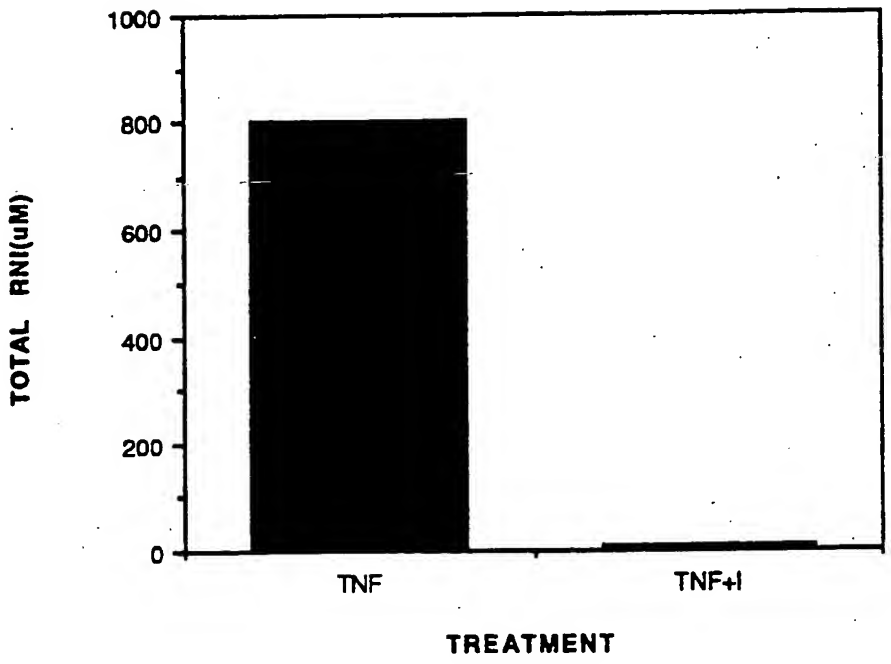


Fig 5

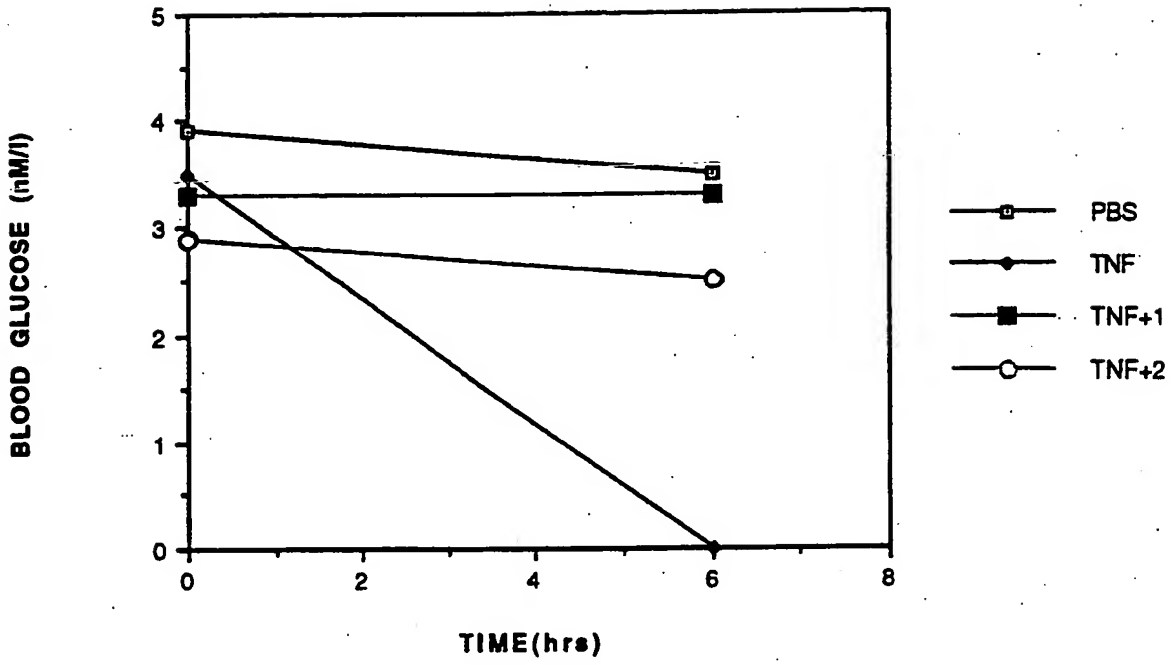


Fig 6

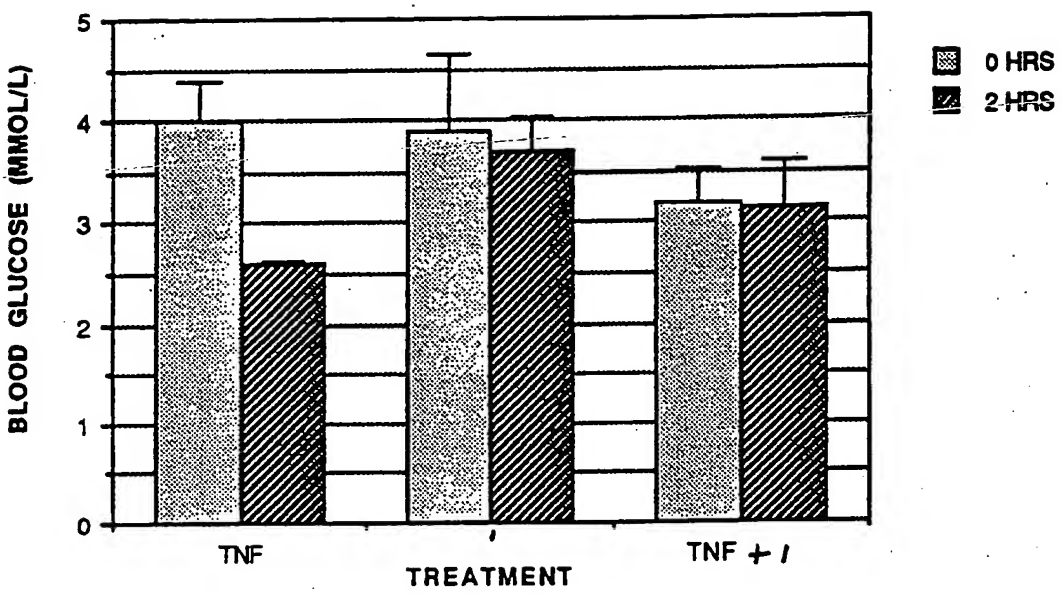


Fig 7

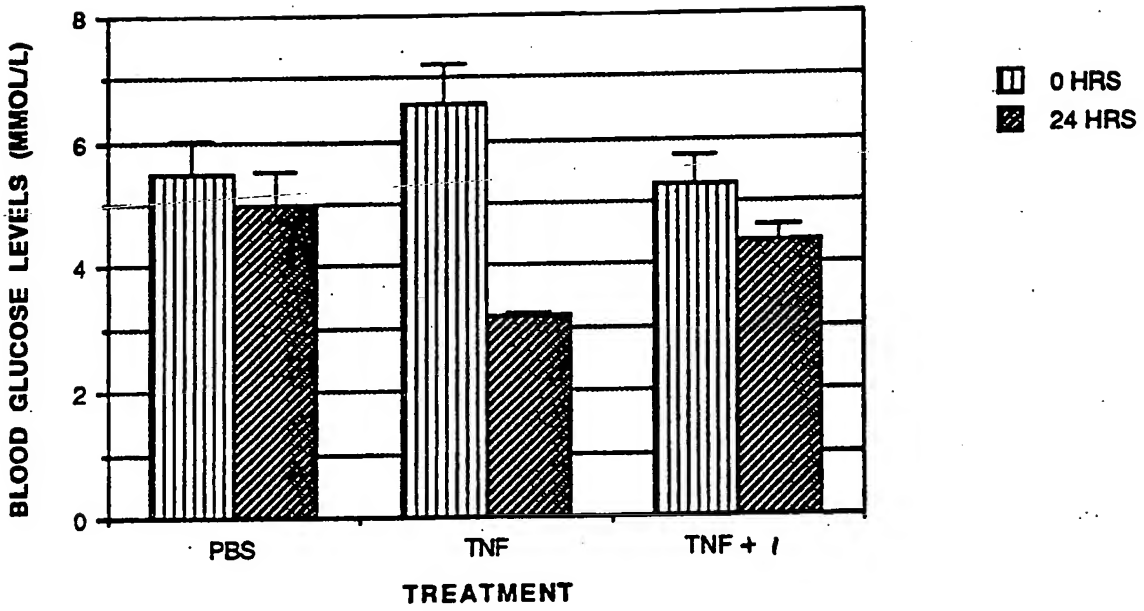

BLOOD GLUCOSE LEVELS (MMOL/L)
8
6
4
2
0
PBS
TNF
TNF + I
TREATMENT
0 HRS
24 HRS

Fig 8

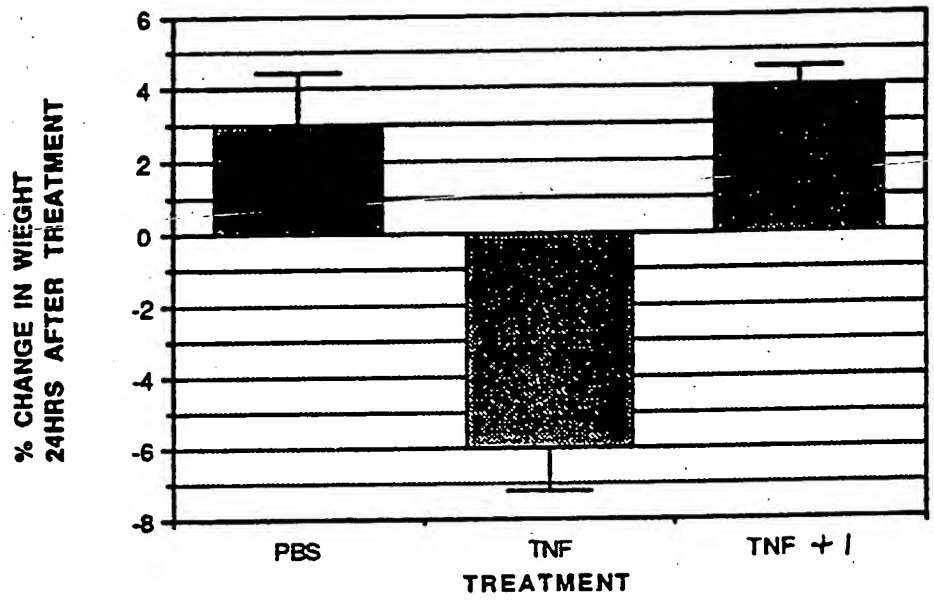

% CHANGE IN WIEGHT
24HRS AFTER TREATMENT
6
4
2
0
-2
-4
-6
-8
PBS
TNF
TNF + I
TREATMENT

Fig 9

10/22

Fig 10

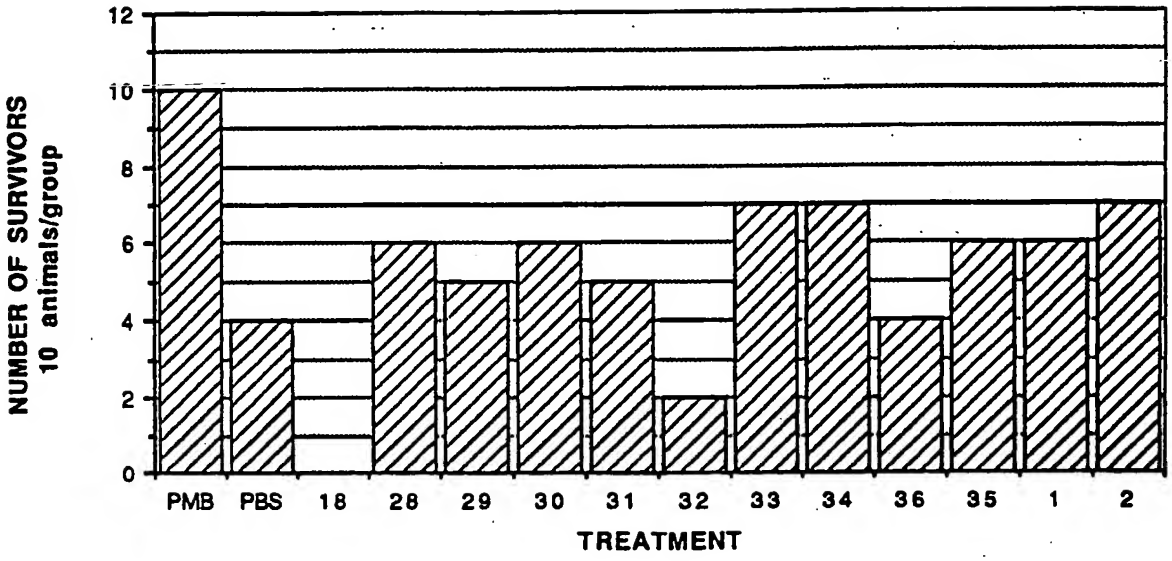

NUMBER OF SURVIVORS
10 animals/group
12
10
8
6
4
2
0
PMB
PBS
18
28
29
30
31
32
33
34
36
35
1
2
TREATMENT

Fig 11

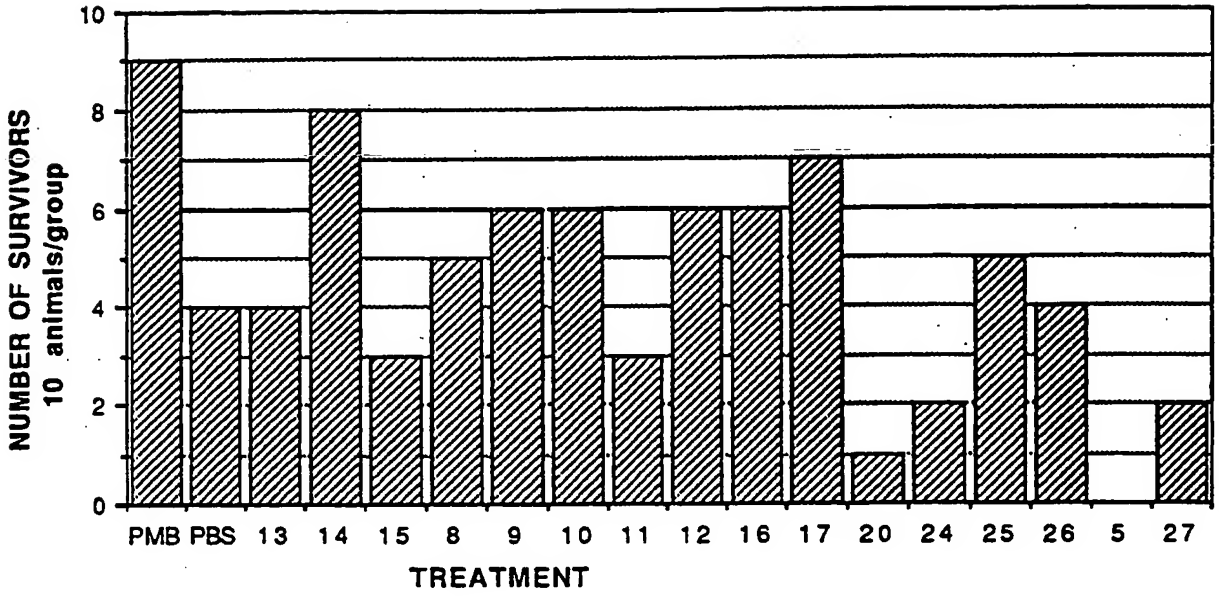

NUMBER OF SURVIVORS
10 animals/group
0
2
4
6
8
10
PMB PBS 13 14 15 8 9 10 11 12 16 17 20 24 25 26 5 27
TREATMENT

Fig 12

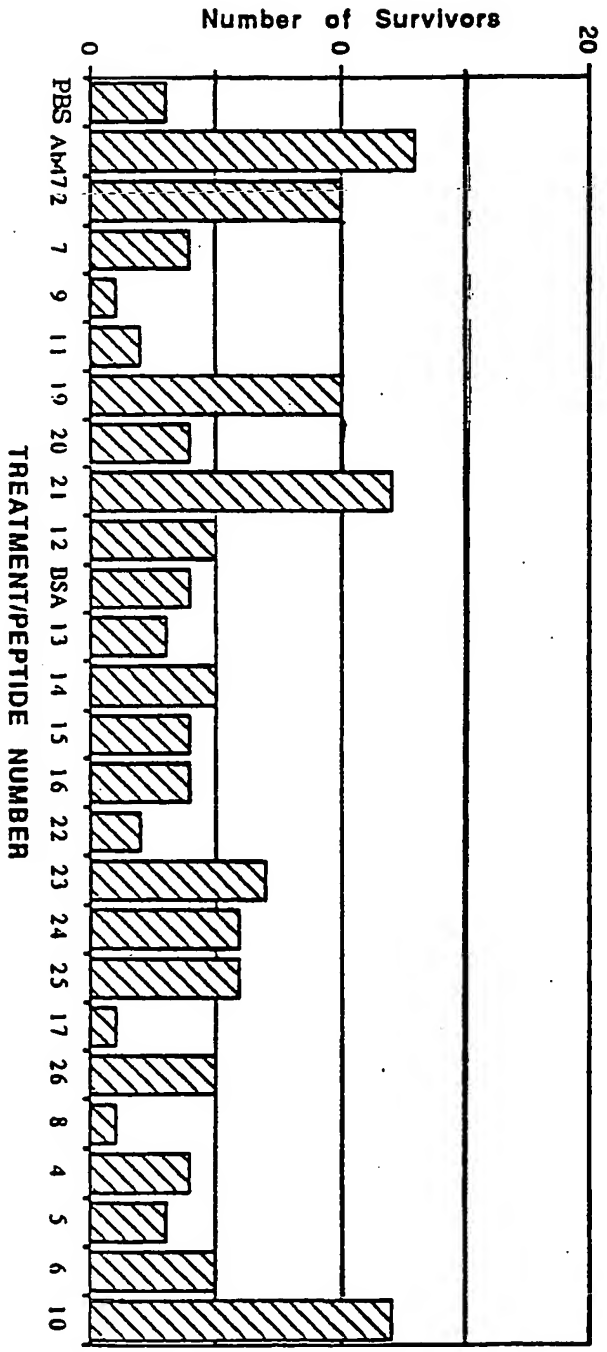

Number of Survivors
0
0
20
PBS AM72 7 9 11 19 20 21 12 BSA 13 14 15 16 22 23 24 25 17 26 8 4 5 6 10
TREATMENT/PEPTIDE NUMBER

Fig 13

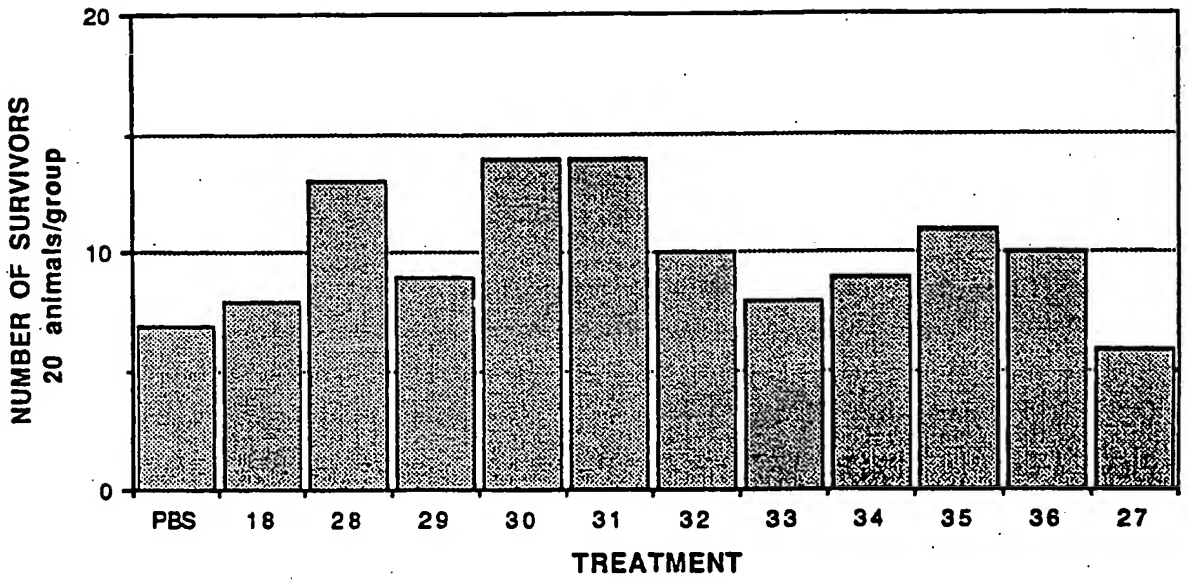

20
10
0
NUMBER OF SURVIVORS
20 animals/group
PBS
18
28
29
30
31
32
33
34
35
36
27
TREATMENT

FIG 14

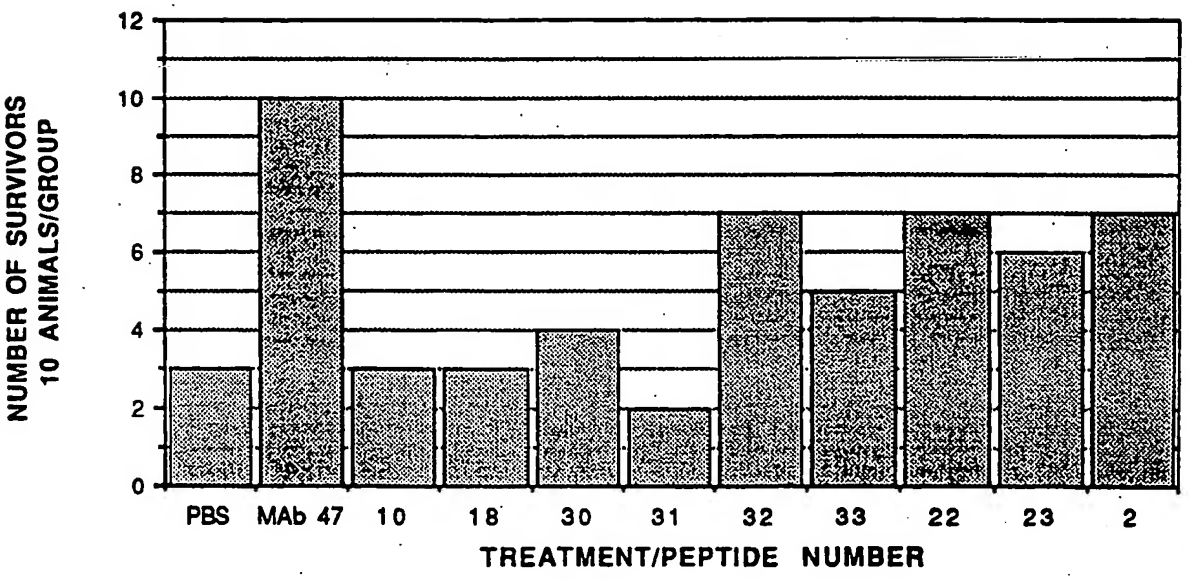

NUMBER OF SURVIVORS
10 ANIMALS/GROUP
12
10
8
6
4
2
0
PBS
MAb 47
10
18
30
31
32
33
22
23
2
TREATMENT/PEPTIDE NUMBER

FIG 15

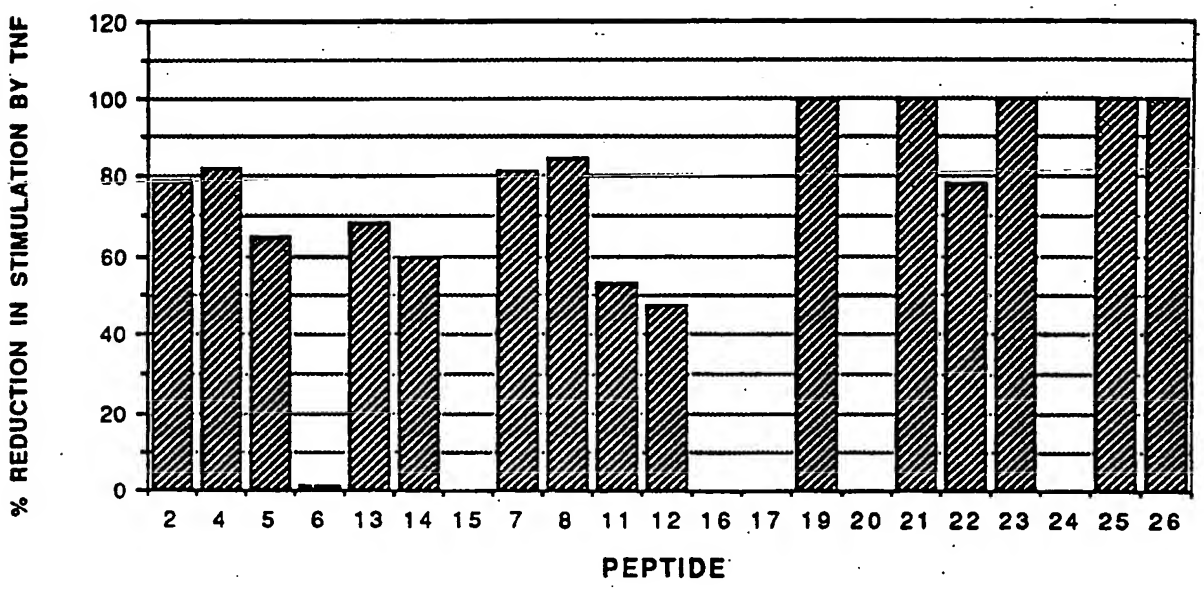
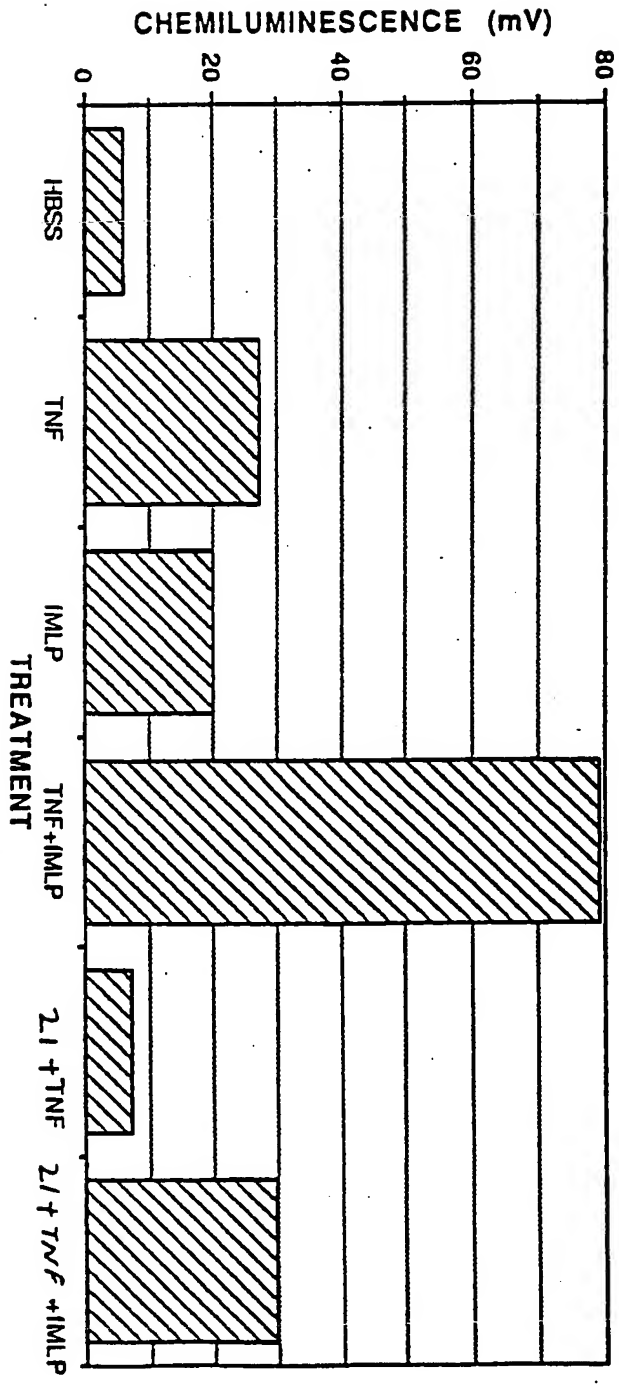

% REDUCTION IN STIMULATION BY TNF
120
100
80
60
40
20
0
2 4 5 6 13 14 15 7 8 11 12 16 17 19 20 21 22 23 24 25 26
PEPTIDE

FIG 16 16/22


CHEMILUMINESCENCE (mV)
0
20
40
60
80
HBSS
TNF
IMLP
TNF+IMLP
2.1 +TNF
2.1 + TNF +IMLP
TREATMENT

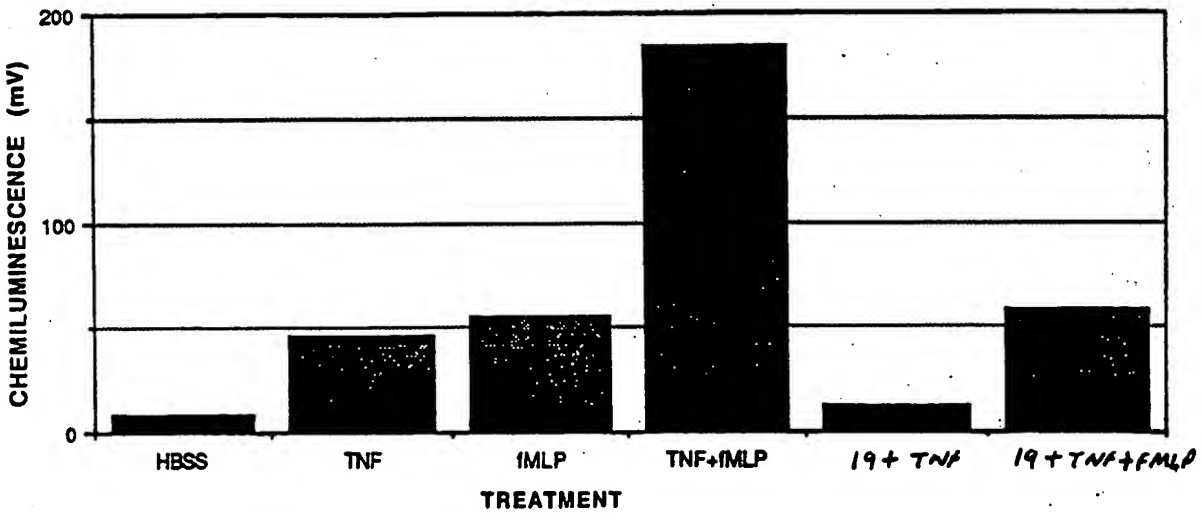

200
100
0
CHEMILUMINESCENCE (mV)
HBSS
TNF
fMLP
TNF+fMLP
19+ TNF
19+TNF+FMLP
TREATMENT

FIG 17

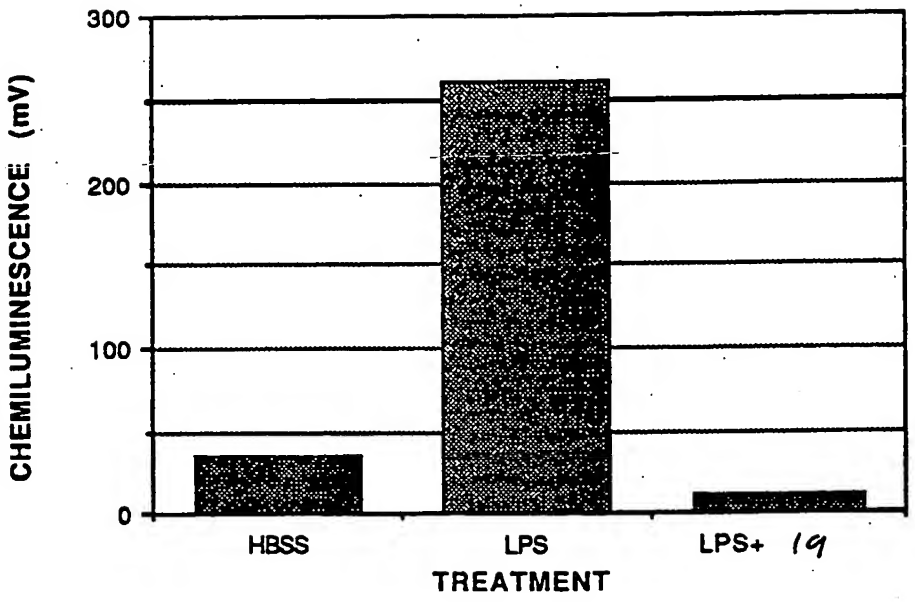
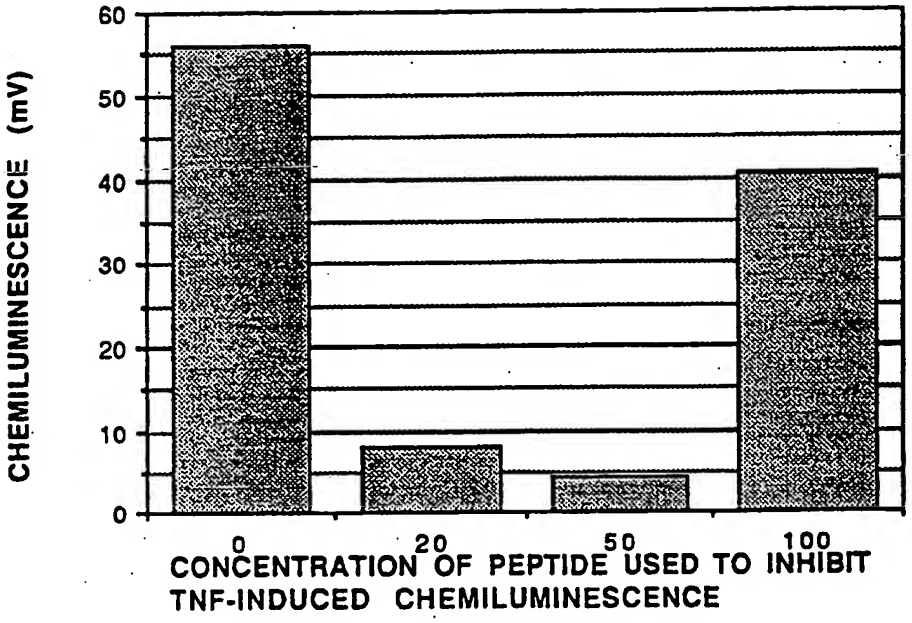

300
200
100
0
CHEMILUMINESCENCE (mV)
HBSS
LPS
LPS+ 19
TREATMENT

FIG 18

FIG. 19


CHEMILUMINESCENCE (mV)
60
50
40
30
20
10
0
0
20
50
100
CONCENTRATION OF PEPTIDE USED TO INHIBIT
TNF-INDUCED CHEMILUMINESCENCE

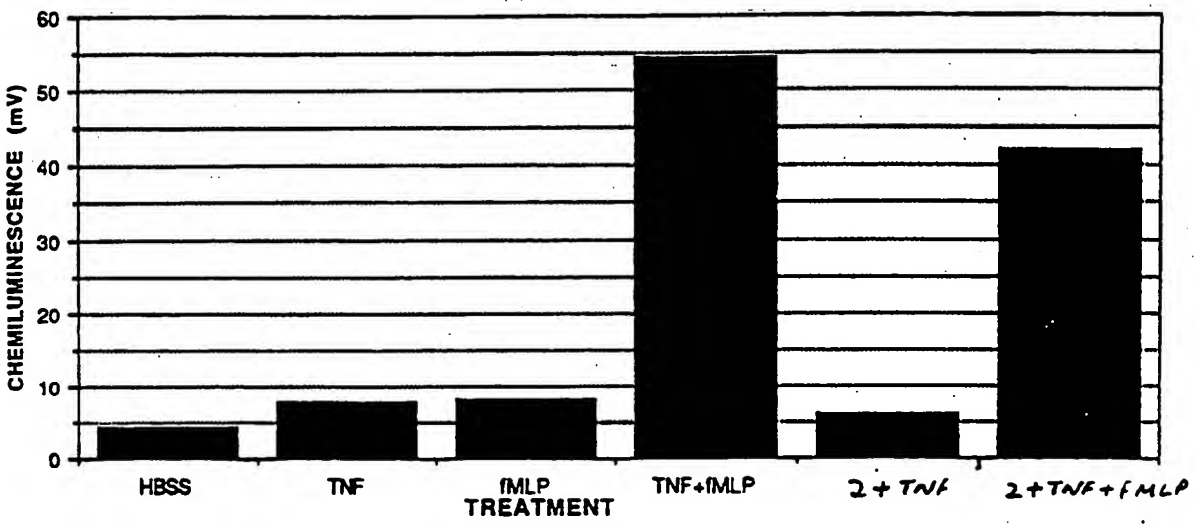
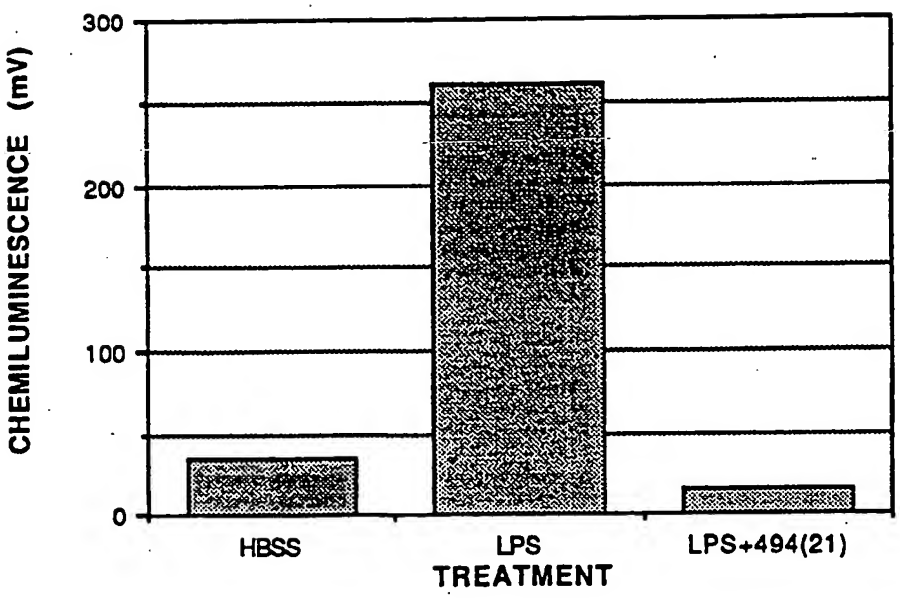

CHEMILUMINESCENCE (mV)
60
50
40
30
20
10
0
HBSS
TNF
fMLP
TNF+fMLP
2+TNF
2+TNF+fMLP
TREATMENT

FIG 20

FIG 21


CHEMILUMINESCENCE (mV)
300
200
100
0
HBSS
LPS
LPS+494(21)
TREATMENT

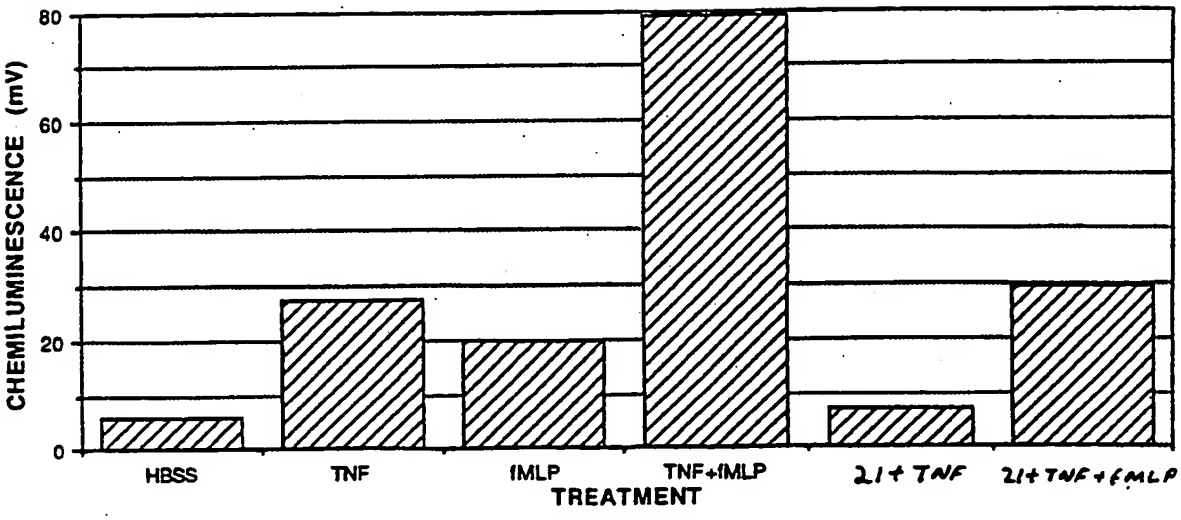

CHEMILUMINESCENCE (mV)
80
60
40
20
0
HBSS
TNF
fMLP
TNF+fMLP
2I+TNF
2I+TNF+fMLP
TREATMENT

FIG. 22

INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all)[6]

According to International Patent classification (IPC) or to both National Classification and IPC

Int. Cl.[5] C07K 7/06, 7/08, 7/10, A61K 37/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	C07K 7/06, 7/08, 7/10, C07C 103/52.
Chem. Abs. online	Keywords: Tumo(u)r Necrosis Factor OR TNF
CAS online registry	PROTEIN SEQUENCE SEARCH

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

AU: IPC As Above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category*	Citation of Document, [11] with indication, where appropriate of the relevant passages [12]	Relevant to Claim No [13]
A	Derwent Abstract Accession no. 90-143138/19, Classes B04 and D16, JP,A, 02-088598 (SOMA G) 28 March 1990 (28.03.90)	1-14
A	Derwent Abstract Accession no. 91-152432/21, Classes B04 and D16, JP,A, 03-087196 (TEIJIN K K) 11 April 1991 (11.04.91)	1-14
A	Derwent Abstract Accession no. 91-145993/20, Classes B04 and D16, JP,A, 03-083587 (TEIJIN K K) 9 April 1991 (09.04.91)	1-14
A	Derwent Abstract Accession no. 91-145992/20, Classes B04 and D16, JP,A, 03-083586 (TEIJIN K K) 9 April 1991 (09.04.91)	1-14

* Special categories of cited documents : [10]

"A" Document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior t the international filing date but later than the priority date claimed

"T" Later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
28 August 1992 (28.08.92)	-7 SEP 1992 (07.09.92)
International Searching Authority	Signature of Authorized Officer
AUSTRALIAN PATENT OFFICE	A BESTOW

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim numbers ..., because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers ..., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers ..., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4a

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

ANTIMICROBIAL AMINO ACID SEQUENCES DERIVED FROM ALPHA-MELANOCYTE-STIMULATING HORMONE

TECHNICAL FIELD

The present invention relates to new pharmaceutical compositions useful as antimicrobial agents, including, for example, for use in reducing the viability of microbes, reducing the germination of yeasts, killing microbes without reducing the killing of microbes by human neutrophils, for treating inflammation in which there is microbial infection without reducing microbial killing, and for increasing the accumulation of cAMP in microbes. More particularly, this invention relates to antimicrobial agents including amino acid sequences derived from alpha-melanocyte-stimulating hormone (α-MSH) and biologically functional equivalents thereof.

BACKGROUND OF THE INVENTION

Mucosal secretions, phagocytes, and other components of the nonspecific (innate) host defense system initiate the response to microbial penetration before time-consuming adaptive immunity starts. Survival of plants and invertebrates, which lack adaptive immunity, illustrates effectiveness of host defense based on such innate mechanisms.

Endogenous antimicrobial peptides are significant in epithelia, the barrier to environmental challenge that provides the first line of defense against pathogens. Production of natural antimicrobial peptides by phagocytes has been recognized for a long time. These natural antimicrobial peptides generally have a broad spectrum of activity against bacteria, fungi, and viruses. Martin, E., Ganz, T., Lehrer, R.I., Defensins and Other Endogenous Peptide Antibiotics of Vertebrates, *J. Leukoc. Biol.* 58, 128-136 (1995); Ganz, T., Weiss, J., Antimicrobial Peptides of Phagocytes and Epithelia, *Sem. Hematol.* 34, 343-354 (1997).

The search for antimicrobial peptides, however, has been painfully difficult and slow. A rare and difficult find has been bactericidal/permeability-increasing protein ("BPI"), which has been used successfully to treat children with severe meningococcal sepsis. Giroir, B.P., Quint, P.A., Barton, P., Kirsh, E.A., Kitchen, L., Goldstein, B., Nelson, B.J., Wedel, N.I., Carrol, S.F., Scannon, P.J., Preliminary Evaluation of Recombinant Amino-terminal Fragment of Human Bactericidal/Permeability-increasing Protein in Children with Severe Meningococcal Sepsis, *Lancet* 350,1439-1443 (1997).

It would be an important advance in the science to identify the most active amino acid sequences responsible for broad spectrum antimicrobial activity, which would also be useful in new prophylactic and therapeutic antimicrobial treatments.

SUMMARY OF INVENTION

According to the approach of the invention, the existence of homologs of vertebrate antimicrobial peptides in invertebrates suggests that such peptides are ancestral components of the host defense system. Some of these peptides, or their synthetic homologs, might be suggested for use as therapeutic agents for controlling microbes.

Alpha-melanocyte-stimulating hormone ("α-MSH") is an ancient 13 amino acid peptide produced by post-translational processing of the larger precursor molecule proopiomelanocortin and shares the 1-13 amino acid sequence with adrenocorticotropic hormone ("ACTH"). Eberle, A. N., The Melanotropins, Karger, Basel, Switzerland (1988). α-MSH is known to be secreted by many cell types including pituitary cells, monocytes, melanocytes, and keratinocytes. Lipton, J. M., Catania, A., Anti-inflammatory Influence of the Neuroimmunomodulator α-MSH, *Immunol. Today* 18, 140-145 (1997). α-MSH occurs in the skin of rats and in the human epidermis. Thody, A.J., Ridley, K., Penny, R.J., Chalmers, R., Fisher, C., Shuster, S., MSH Peptides Are Present in Mammalian Skin, *Peptides* 4, 813-816 (1983). α-MSH is also found in the mucosal barrier of the gastrointestinal tract in intact and hypophysectomized rats. Fox, J.A.E.T., Kraicer, J., Immunoreactive α-Melanocyte Stimulating Hormone. its Distribution in the Gastrointestinal Tract of Intact and Hypophysectomized Rats, *Life. Sci.* 28, 2127-2132 (1981). We recently found that human duodenal cells produce α-MSH in culture. Catania et al., unpublished. The presence in barrier organs of this ancient peptide, relatively invariant in amino acid sequence over approximately 300 million years, suggests that it may have a role in the nonspecific (innate) host defense system.

α-Melanocyte-stimulating hormone is known to have potent antipyretic and anti-inflammatory properties. Lipton, J.M., Antipyretic and Anti-inflammatory Lys Pro Val Compositions and Method of Use, U.S. Patent No. 5,028,592, issued July 2, 1991, which is incorporated herein by reference in its entirety; Lipton, J.M., Antipyretic and Anti-inflammatory Lys Pro Val Compositions and Method of Use, U.S. Patent No. 5,157,023, October 20, 1992, which is incorporated herein by reference in its

entirety; Catania, A., Lipton, J. M., α-Melanocyte Stimulating Hormone in the Modulation of Host Reactions, *Endocr. Rev.* **14**, 564-576 (1993); Lipton, J. M., Catania, A., Anti-inflammatory Influence of the Neuroimmunomodulator α-MSH, *Immunol. Today* **18**, 140-145 (1997). α-MSH reduces production of proinflammatory mediators by host cells *in vitro*. Rajora, N., Ceriani, G., Catania, A., Star, R.A., Murphy, M. T., Lipton, J. M., α-MSH Production, Receptors, and Influence on Neopterin, in a Human Monocyte/macrophage Cell Line, *J. Leukoc. Biol.* **59**, 248-253 (1996); Star, R.A, Rajora, N., Huang, J., Stock, R.C., Catania, A., Lipton, J. M., Evidence of Autocrine Modulation of Macrophage Nitric Oxide Synthase by α-MSH, *Proc. Natl. Acad. Sci. (USA)* **92**, 8016-8020 (1995). α-MSH also reduces production of local and systemic reactions in animal models of inflammation. Lipton, J. M., Ceriani, G., Macaluso, A., McCoy, D., Carnes, K., Biltz, J., Catania, A., Anti-inflammatory Effects of the Neuropeptide α-MSH in Acute, Chronic, and Systemic Inflammation, *Ann. N. Y. Acad. Sci.* **741**, 137-148 (1994); Rajora, N., Boccoli, G., Burns, D., Sharma, S., Catania, A., Lipton, J.M., α-MSH Modulates Local and Circulating Tumor Necrosis Factor A in Experimental Brain Inflammation, *J. Neurosci.* **17**, 2181-2186 (1997). The "core" α-MSH sequence (4-10) has learning and memory behavioral effects but little antipyretic and anti-inflammatory activity. Lipton, J. M., Catania, A., Anti-inflammatory Influence of the Neuroimmunomodulator α-MSH, *Immunol. Today* **18**, 140-145 (1997). The active message sequence for these antipyretic and anti-inflammatory activities resides in the C-terminal amino acid sequence of α-MSH, that is, lysine-proline-valine ("Lys-Pro-Val" or "KPV"), which has activities *in vitro* and *in vivo* that parallel those of the parent molecule. Richards, D.B., Lipton, J.M., Effect of α-MSH (11-13) (Lysine-proline-valine) on Fever in the Rabbit, *Peptides* **5**, 815-817 (1984); Hiltz, M. E., Lipton, J.M., Anti-inflammatory Activity of a COOH-terminal Fragment of the Neuropeptide α-MSH, *FASEB J.* **3**, 2282-2284 (1989). These peptides are known to have extremely low toxicity. Lipton, J.M., Catania, A., Anti-inflammatory Influence of the Neuroimmunomodulator α-MSH, *Immunol. Today* **18**, 140-145 (1997).

Melanocortin peptides, including α-MSH, ACTH, and other amino acid sequences derived from α-MSH or ACTH, have heretofore not been studied for potential antimicrobial activity, and there has been no suggestion that melanocortin peptides would have such activity.

According to the invention, it has been determined that α-MSH and certain other amino acid sequences derived from α-MSH have significant antimicrobial uses, including for example, for use in reducing the viability of microbes, reducing the germination of yeasts, killing microbes without reducing the killing of microbes by human neutrophils, for treating inflammation in which there is microbial infection without reducing microbial killing, and increasing the accumulation of cAMP in microbes.

According to a broad aspect of the invention, the antimicrobial agent is selected from the group consisting of one or more peptides including the C-terminal amino acid sequence of α-MSH, that is, KPV, one or more peptides including the amino acid sequence MEHFRWG, or a biologically functional equivalent of any of the foregoing.

According to one aspect of the invention, the antimicrobial agent is selected from the group consisting of one or more peptides including the C-terminal amino acid sequence of α-MSH, that is, KPV, or a biologically functional equivalent of any of the foregoing. The KPV sequence is the amino acid sequence α-MSH (11-13). This type of antimicrobial agent includes a dimer of the amino acid sequence KPV, such as VPKCCKPV.

According to a further aspect of the invention, the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence HFRWGKPV or a biologically functional equivalent of any of the foregoing. The HFRWGKPV sequence is the amino acid sequence α-MSH (6-13).

According to a still further aspect of the invention, the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence

SYSMEHFRWGKPV or a biologically functional equivalent of any of the foregoing. The SYSMEHFRWGKPV sequence is the entire amino acid sequence of α-MSH (1-13).

According to yet another aspect of the invention, the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence MEHFRWG or a biologically functional equivalent of any of the foregoing. The MEHFRWG sequence is sometimes referred to as the "core" amino acid sequence of α-MSH, that is, α-MSH (4-10).

With these aspects of the invention, it is believed that the shorter amino acid sequences tend to be more effective. Preferably, the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to thirteen. Still more preferably, the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to eight. Based on the experimental results obtained thus far, the tripeptide KPV is the most effective.

According to the invention, an effective concentration of the antimicrobial agent is at least 10^{-12} molar, and more preferably the concentration of the antimicrobial agent is at least 10^{-6} molar.

It is fully expected that these peptides, which have extremely low toxicity, will be effective in animal and human subjects without adverse effect.

These and other aspects of the invention will be apparent to those persons skilled in the art upon reading the following description of the experimental evidences and discussion.

BRIEF DESCRIPTION OF THE DRAWING

The accompanying figures of the drawing are incorporated into and form a part of the specification to provide illustrative examples of the present invention and to explain the principles of the invention. The figures of the drawing are only for purposes of illustrating preferred and alternate embodiments of how the invention can be made and used. It is to be understood, of course, that the

drawing is intended to represent and illustrate the concepts of the invention. The figures of the drawing are not to be construed as limiting the invention to only the illustrated and described examples. Various advantages and features of the present invention will be apparent from a consideration of the written specification and the accompanying figures of the drawing wherein:

Figure 1 shows the effect of α-MSH (1-13), α-MSH (11-13), and the "KPV dimer" on *S. aureus* colony forming units ("CFU") compared to controls. All three molecules significantly decreased S. aureus colony forming units over a broad range of peptide concentrations.

Figure 2 shows that treatment with urokinase increases *S. aureus* colony formation, but that the addition of α-MSH (1-13) or (11-13) significantly inhibited this urokinase-enhancing effect. *$p<0.001$ vs urokinase alone.

Figure 3 shows the effect of α-MSH (1-13), α-MSH (11-13), and the "KPV dimer" on *C. albicans* colony forming units ("CFU") compared to controls. All three molecules significantly decreased C. albicans colony forming units over a broad range of peptide concentrations.

Figure 4 shows a comparison of candidacidal activity of certain melanocortin peptides and fluconazole (all 10^{-6} M). The most effective of the melanocortin peptides were those including the C-terminal amino acid sequence of α-MSH, for example, α-MSH (1-13), α-MSH (6-13), and α-MSH (11-13).

Figure 5A shows untreated germination of *C. albicans*, i.e, blastospores.

Figure 5B shows horse serum-induced germination of *C. albicans*.

Figure 5C shows the effect of α-MSH (1-13) treatment on germination of *C. albicans*.

Figure 5D shows the effect of α-MSH (11-13) treatment on germination of *C. albicans*.

Figure 6 shows the effect of α-MSH (1-13) and α-MSH (11-13) on *C. albicans* killing by human neutrophils. Values are expressed as percent increase in killing vs medium alone. Scores are means ± SEM.

Figure 7 shows the effect of α-MSH (1-13), α-MSH (11-13), and forskolin on cAMP content of *C. albicans*.

Figure 8 shows the inhibitory effect of α-MSH (1-13), α-MSH (11-13), and forskolin on *C. albicans* colony forming units.

DETAILED DESCRIPTION OF THE INVENTION

I. Materials and Methods

Peptides

The peptides used in this research included: α-MSH (1-13), (4-10), (6-13), and (11-13), all of which were N-acetylated and C-amidated, and ACTH (1-39) and (18-39) (CLIP). Another peptide used in this research included a dimer of the amino acid sequence KPV, specifically VPKCCKPV, which also was N-acetylated and C-amidated (the "KPV dimer"). The KPV dimer can be chemically represented as NH_2-Lys-Pro-Val-AcCys-CysAc-Val-Pro-Lys-NH_2. The peptides were prepared by solid-phase peptide synthesis and purified by reversed-phase high performance liquid chromatography, as kindly provided by Dr. Renato Longhi, CNR, Milano.

Organism and culture conditions

S. aureus (ATCC 29213) and *C. albicans* (clinical isolate) were obtained from the collection of the Department of Microbiology, Ospedale Maggiore di Milano. *C. albicans* were maintained on Sabouraud's agar slants and periodically transferred to Sabouraud's agar plates and incubated for 48 hours at 28°C. To prepare stationary growth phase yeast, a colony was taken from the agar plate and transferred into 30 ml Sabouraud-dextrose broth and incubated for 72 hours at 32°C. Cells were centrifuged at 1000 x g for 10 minutes and the pellet was washed twice with distilled water. Cells were counted and suspended in Hank's balanced salt solution ("HBSS") to the desired concentration. Viability, determined by the exclusion of 0.01 % methylene blue, remained > 98%.

Trial of melanocortin peptides on *S. aureus* viability

S. aureus ($1x10^6$/ml in HBSS) was incubated in the presence or absence of α-MSH (1-13), α-MSH (11-13), or the "KPV dimer" at concentrations in the range of 10^{-15} to 10^{-4} M for 2 hours at 37°C. Cells were then washed in cold distilled water and diluted with HBSS to a concentration of 100 organisms/ml. One ml aliquots were dispensed on blood agar plates and incubated for 24 hours at 37°C. Organism viability was estimated from the number of colonies formed.

In experiments on *S. aureus* we determined the influence of α-MSH on urokinase-induced growth-enhancement. Hart, D.A., Loule, T., Krulikl, W., Reno, C., Staphylococcus Aureus Strains Differ in Their in Vitro Responsiveness to Human Urokinase: Evidence That Methicillin-resistant Strains Are Predominantly Nonresponsive to the Growth-enhancing Effects of Urokinase, *Can. J. Microbiol.* **42,** 1024-31 (1966). *S. aureus* (10^6 / 100 ml) were incubated for 4 hours at 37 °C with recombinant human urokinase 500 U (Lepetit, Milan, Italy) in a shaking water bath, in the presence or absence of α-MSH (1-13) or (11-13) 10^{-6} M. Appropriate dilutions of *S. aureus* were dispensed on agar plates and colonies counted after 24 hours incubation at 37°C.

Trial of melanocortin peptides on *C. albicans* viability

C. albicans ($1x10^6$/ml in HBSS) was incubated in the presence or absence of α-MSH (1-13), α-MSH (11-13), or the "KPV dimer" at concentrations in the range of 10^{-15} to 10^{-4} M for 2 hours at 37°C. Cells were then washed in cold distilled water and diluted with HBSS to a concentration of 100 organisms/ml. One ml aliquots were dispensed on blood agar plates and incubated for 48 hours at 37°C. Organism viability was estimated from the number of colonies formed.

In subsequent experiments using similar procedures we compared activity of α-MSH (4-10), (6-13), (11-13), ACTH (1-39), (18-39), and fluconazole, the latter being a known antifungal agent. Melanocortin peptides and fluconazole were tested in concentrations of 10^{-6} to 10^{-4}M. There were at least six replicates for each concentration of peptide.

Trial of α-MSH peptides on *C. albicans* germination

C. albicans from stationary phase cultures were washed twice with distilled water and suspended in HBSS to a final concentration of 2 x 10^6/ml. Hyphal growth was induced by addition of 10% inactivated horse serum (GIBCO/BRL, Paisley, Great Britain) to yeast incubated for 45 minutes at 37°C with continuous shaking. Horse serum was removed by washing cells twice with HBSS and incubation was continued for 60 minutes at 37°C in the presence of α-MSH (1-13), (6-13), or (11-13) at a concentration of 10^{-6} M with continuous shaking. The percentage of filamentous cells was evaluated under a light microscope with the aid of a hemocytometer. Experiments were run in triplicate and at least 200 cells were scored. Photomicrographs were taken with a MC100 camera attached to an Axioskop Zeiss microscope.

Trial of α-MSH peptides on *C. albicans* killing by human neutrophils

Venous blood (20 ml) from healthy volunteers was anticoagulated with heparin. Neutrophils were isolated using dextran sedimentation and Ficoll-Hypaque (Sigma Chemical Co., St. Louis, Missouri, USA) centrifugation. Erythrocytes were lysed via hypotonic shock. Neutrophils represented at least 97% of the cell suspension. Cell viability, estimated by trypan blue exclusion, was > 98%. Neutrophils were suspended to final concentration in HBSS.

C. albicans (1x10^6) were opsonized with human AB serum in a shaking water bath for 30 minutes at 37°C. Organisms were then incubated with neutrophils in presence of medium alone or medium with α-MSH (1-13) or α-MSH (11-13) in concentrations of 10^{-15} to 10^{-4} M in a shaking water bath for 2 hours at 37°C. After incubation, the culture tubes were placed on ice to stop growth and extracellular organisms were washed twice with centrifugation at 1000 x g at 4°C. A 2.5% sodium desoxycholate solution was added to the suspension and the tubes were shaken for 5 min. Cold distilled water was added to obtain a suspension of 10^6 cells/ml. Two 1/100 serial dilution in HBSS were made to obtain a final suspension of 100 cells/ml. Aliquots of 1 ml were dispensed on

blood agar plates and incubated for 48 hours at 37°C. Colony forming units ("CFU") were counted at the end of the incubation period. Experiments were run in triplicate and repeated using blood from 5 different donors.

Trial of α-MSH peptides on cAMP accumulation

C. albicans (10^6/ml), permeabilized with toluene/ethanol, were incubated at 37°C with continuous shaking in the presence of 10^{-6} M α-MSH (1-13), (11-13), forskolin, an agent known to increase intracellular cAMP, or in medium alone. The reaction was stopped after 3 minutes by the addition of ice cold ethanol. cAMP was measured in duplicate using a commercial enzyme immunoassay (EIA) kit (Amersham, United Kingdom) after extraction via the liquid-phase method according to manufacturer's instructions. The effect of forskolin (10^{-6} M) on *C. albicans* colony formation was determined using the same procedures as for α-MSH peptides.

Statistical analysis

One-way analysis of variance and Student's *t* test were used to analyze the data. Probability values <0.05 were considered significant.

II. Results

α-MSH Peptides inhibited *S. aureus* colony formation

α-MSH peptides (1-13) and (11-13) inhibited *S. aureus* colony formation (Fig. 1). A dimer of the amino acid sequence KPV, specifically, NH_2-Lys-Pro-Val-AcCys-CysAc-Val-Pro-Lys-NH_2, (the "KPV dimer") also inhibited S. aureus colony formation (Fig. 1). The inhibitory effect occurred over a wide range of concentrations and was significant ($p<0.01$) with peptide concentrations of 10^{-12} to 10^{-4} M.

Treatment with urokinase increased *S. aureus* colony formation and addition of α-MSH (1-13) or (11-13) at concentrations of 10^{-6} M significantly inhibited the enhancing effect of urokinase (Fig. 2).

α-MSH Peptides inhibited *C. albicans* colony formation

C. albicans colony forming units ("CFU") were greatly reduced by α-MSH (1-13) and (11-13) (Fig. 3). A dimer of the amino acid sequence KPV, specifically, KPVCCVPK (the "KPV dimer") also inhibited C. albicans colony formation (Fig. 3). Concentrations of all three peptides from 10^{-12} to 10^{-4} M had significant inhibitory influences on CFU ($p<0.01$ *vs* control).

In experiments comparing the relative potency of 10^{-6} M melanocortin peptides in reducing *C. albicans* viability, α-MSH (11-13), (6-13), and (1-13) were the most effective (Fig.4). Their inhibitory activity was similar to that of equimolar fluconazole. The "core" α-MSH sequence (4-10), which has behavioral effects but little anti-inflammatory activity, caused approximately 50% inhibition of CFU. Although this inhibitory effect was substantial ($p<0.01$ *vs* control), it was significantly less than that caused by α-MSH fragments bearing the KPV signal sequence, i.e., α-MSH (6-13) and (11-13) ($p<0.01$), or the parent molecule α-MSH (1-13) ($p<0.05$). ACTH (1-39) and the ACTH fragment (18-39) did not reduce *C. albicans* viability (Fig.4). Even higher concentrations of these ACTH peptides (up to 10^{-4} M) were likewise ineffective in reducing *C. albicans* CFU (results not shown in the figures).

α-MSH peptides reduced *C. albicans* germination

Coincubation of *C. albicans* with α-MSH (1-13) or (11-13) inhibited germ tube formation induced by horse serum (Figs. 5A-D). α-MSH (1-13) caused 28-32% reduction in the number of filamentous cells; the tripeptide inhibited germination by 54-58%. The octapeptide α-MSH (6-13) had similar activity (approximately 50% inhibition) (not shown).

α-MSH peptides enhanced *C. albicans* killing by human neutrophils

α-MSH (1-13) and (11-13) enhanced killing of *C. albicans* by human neutrophils when administered in concentrations of 10^{-12} to 10^{-4} ($p<0.01$) (Fig.6). Therefore, enhanced killing occurred over a very broad range of concentrations including picomolar concentrations, i.e., the quantity of α-MSH found in human plasma. Catania, A., Airaghi, L., Garofalo, L., Cutuli, M., Lipton, J.M., The Neuropeptide α-MSH in AIDS and Other Conditions in Humans, *Ann. N. Y. Acad. Sci.* **840**, 848-856 (1998).

α-MSH peptides increased cAMP accumulation

Because many of the effects of α-MSH are known to be mediated by induction of cAMP, we measured effects of α-MSH peptides on cAMP accumulation in *C. albicans*. α-MSH (1-13) and (11-13) enhanced cAMP content in the yeast (Fig.7). The increase was of the same order of magnitude as that induced by equimolar forskolin, an adenylate cyclase activator (Figs. 7). To determine whether increases in cAMP could be responsible for reduction in CFU, we tested the effects of forskolin on *C. albicans* viability. Results showed that 10^{-6} M forskolin markedly inhibited *C. albicans* CFU relative to control ($p<0.01$). The inhibitory effect was similar to that exerted by α-MSH peptides (Fig. 8).

III. Discussion

Antimicrobial agents against the viability of microbes

The results show that α-MSH (1-13), its C-terminal tripeptide sequence α-MSH (11-13), and other α-MSH fragments have significant antimicrobial effects against at least two major pathogens: *S. aureus* and *C. albicans*. The most effective of the α-MSH peptides were those including the C-terminal amino acid sequence KPV of the α-MSH sequence, i.e., α-MSH (1-13), (6-13), and (11-13). A dimer of the amino acid sequence KPV, specifically, VPKCCKPV (referred to herein as the "KPV dimer") has also been shown to be at least as effective as α-MSH (11-13) against microbes. The α-MSH "core" sequence (4-10), which is known to influence learning and memory, but has little antipyretic and anti-inflammatory influence, was effective, but less so. The ACTH peptides (1-39) and (18-39) did not have significant candidacidal effects. These observations indicate that antimicrobial activity is not common to all melanocortin peptides, but rather that it is specific to α-MSH amino acid sequences, and most particularly to the C-terminal amino-acid sequences of α-MSH.

The antimicrobial effects of these α-MSH peptides occurred over a very broad range of concentrations, including picomolar concentrations that normally occur in human plasma. Catania, A., Airaghi, L., Garofalo, L., Cutuli, M., Lipton, J.M., The Neuropeptide α-MSH in AIDS and Other Conditions in Humans, *Ann. N. Y. Acad. Sci.* 840, 848-856 (1998). This suggests that endogenous α-MSH has a physiological role in natural immunity.

Therefore, these α-MSH peptides are expected to be useful as a broad prophylactic against microbial infection and in the treatment of human and veterinary disorders resulting from microbial invasion. Further, these peptides that likewise have anti-inflammatory activity could be used to treat cases in which both inflammation and microbial invasion coexist, or where the aim is to prevent their coexistence or development.

Antimicrobial agents against germination of yeasts

Yeasts can be major pathogens. For example, *C. albicans* is the leading cause of invasive fungal disease in premature infants, diabetics, surgical patients, and patients with human immunodeficiency virus infection or other immunosuppressed conditions. Despite appropriate therapy, death resulting from systemic *C. albicans* infection in immunocompromised patients is substantial. Wenzel, R.P., Pfaller, M.A., Candida Species: Emerging Hospital Bloodstream Pathogens, *Infect. Control. Hosp. Epidemiol.* **12**, 523-4 (1991); Cartledge, J.D., Midgley, J., Gazzard, B.G., Clinically Significant Azole Cross-resistance in Candida Isolates from HIV-Positive Patients with Oral Candidosis, *AIDS* **11**, 1839-44 (1997). The pathogenesis of *C. albicans* infection involves adhesion to host epithelial and endothelial cells and morphologic switching of yeast cells from the ellipsoid blastospore to various filamentous forms: germ tubes, pseudohyphae, and hyphae. Gow, N.A., Germ Tube Growth of *Candida Albicans*, *Curr. Topics Med. Mycol.* **8**, 43-55 (1997). It is therefore important that α-MSH (1-13) and its C-terminal tripeptide (11-13) not only reduce the viability of yeast, but also reduce germination of yeast.

Antimicrobial and anti-inflammation effects without reducing killing by human neutrophils

Reduced killing of pathogens is a dire consequence of therapy with corticosteroids and nonsteroidal anti-inflammatory drugs during infection. Stevens, D.L., Could Nonsteroidal Anti-inflammatory Drugs (NSAIDs) Enhance Progression of Bacterial Infections to Toxic Shock Syndrome?, *Clin. Infect. Dis.* **21**, 977-80 (1997); Capsoni, F., Meroni, P.L., Zocchi, M.R., Plebani, A.M., Vezio, M., Effect of Corticosteroids on Neutrophil Function: Inhibition of Antibody-dependent Cell-mediated Cytotoxicity (ADCC), *J. Immunopharmacol.* **5**, 217-30 (1983). This effect could be particularly dangerous in the immunocompromised host.

α-MSH has potent anti-inflammatory influences in models of acute, chronic, and systemic inflammation. Its wide spectrum of activity and low toxicity suggest that α-MSH is useful for

treatment of inflammation in human and veterinary disorders. It was, therefore, important to learn the influence of α-MSH peptides on *C. albicans* killing by phagocytes. This is especially important because α-MSH is known to inhibit neutrophil chemotaxis. Catania, A., Rajora N., Capsoni, F., Minonzio, F., Star, R.A., Lipton, J.M., The Neuropeptide α-MSH Has Specific Receptors on Neutrophils and Reduces Chemotaxis in Vitro, *Peptides* 17, 675-679 (1996). In the absence of trial, it could have been expected to reduce killing by human neutrophils, despite the direct antimicrobial effect. Results of the present research indicate that α-MSH peptides do not reduce killing but rather enhance it, likely as a consequence of the direct candidacidal effect. Therefore, anti-inflammatory agents such as α-MSH peptides that have antimicrobial effects are expected to be very useful in clinical practice.

Theoretical discussion and cAMP accumulation

An important question concerns how α-MSH peptides exert their antimicrobial effects and whether they operate like other natural antimicrobial agents.

It is known that α-MSH shares a number of similarities with other natural antimicrobial peptides such as the defensins or the cathelicidins:

1) it is produced in mammals but also in primitive organisms that lack adaptive immunity. Eberle, A. N., *The Melanotropins*. Karger, Basel, Switzerland (1988).

2) like known antimicrobial peptides, its precursor molecule proopiomelanocortin (POMC) is expressed in phagocytes and epithelia and post-translational proteolytic processing is required to convert it to active α-MSH. Rajora, N., Ceriani, G., Catania, A., Star, R.A., Murphy, M. T., Lipton, J. M., α-MSH Production, Receptors, and Influence on Neopterin, in a Human Monocyte/macrophage Cell Line, *J. Leukoc. Biol.* 59, 248-253 (1996); Luger, T.A., Schauer, E., Trautinger, F., Krutmann, J., Ansel, J., Schwarz, A., Schwartz, T., Production of

Immunosuppressing Melanotropins by Human Keratinocytes, *Ann. N.Y. Acad. Sci.* **680**, 567-570 (1993);

3) it is a cationic peptide; and

4) it has antimicrobial influences against at least two disparate pathogens, a yeast and a bacterium. In addition, α-MSH inhibits HIV-1 replication in acutely and chronically infected monocytes. Barcellini, W., La Maestra, L., Clerici, G., Lipton, J. M., Catania, A., Inhibitory Influences of α-MSH Peptides on Hiv-1 Expression in Monocytic Cells, 12th World AIDS Conference, Geneva, June 28-July 3, 1998. These findings indicate that α-MSH has the broad spectrum of activity of other innate antimicrobial substances.

The mechanism of action of natural antimicrobial agents is only partly understood. Most of these peptides, including the defensins, alter membrane permeability and impair internal homeostasis of the organism. The first contact is made between the cationic groups of the peptide and the negatively charged head of the target membrane. Then, the tertiary structure determines the mode of insertion of the peptide into membranes where they form ion channels or pores that disrupt cell integrity. It is known that cAMP-enhancing agents inhibit mRNA and protein synthesis in *C. albicans*. Bhattacharya, A., Datta, A., Effect of Cyclic AMP on RNA and Protein Synthesis in *Candida Albicans*, *Biochem. Biophys. Res. Commun.* 77:1483-44 (1977).

In the present experiments it is shown that α-MSH induces cAMP accumulation in *C. albicans* and also that the cAMP-inducing agent forskolin inhibited colony formation. Without being limited by this theoretical explanation, it may be that the antimicrobial effect was caused by enhancement of this mediator.

Biologically functional equivalents

As used herein, a biological functional equivalent is defined as an amino acid sequence that is functionally equivalent in terms of biological activity.

Although the specific amino acid sequences described here are effective, it is clear to those familiar with the art that amino acids can be substituted in the amino acid sequence or deleted without altering the effectiveness of the peptides. Further, it is known that stabilization of the α-MSH sequence can greatly increase the activity of the peptide and that substitution of D- amino acid forms for L-forms can improve or decrease the effectiveness of peptides. For example, a stable analog of α-MSH ,[Nle^4,D-Phe^7]- α-MSH, which is known to have marked biological activity on melanocytes and melanoma cells, is approximately 10 times more potent than the parent peptide in reducing fever. Holdeman, M., and Lipton, J.M., Antipyretic Activity of a Potent α-MSH Analog, *Peptides* 6, 273-5 (1985). Further, adding amino acids to the C-terminal α-MSH (11-13) sequence can reduce or enhance antipyretic potency (Deeter, L.B., Martin, L.W., Lipton, J.M., Antipyretic Properties of Centrally Administered α-MSH Fragments in the Rabbit, *Peptides* 9,1285-8 (1989). Addition of glycine to form the 10-13 sequence slightly decreased potency; the 9-13 sequence was almost devoid of activity, whereas the potency of the 8-13 sequence was greater than that of the 11-13 sequence. It is known that Ac-[D-K^{11}]- α-MSH 11-13-NH_2 has the same general potency as the L-form of the tripeptide α-MSH 11-13. Hiltz, M.E., Catania, A., Lipton, J.M., Anti-inflammatory Activity of α-MSH (11-13) Analogs: Influences of Alterations in Stereochemistry, *Peptides* 12, 767-71, (1991). However, substitution with D-proline in position 12 of the tripeptide rendered it inactive. Substitution with the D-form of valine in position 13 or with the D-form of lysine at position 11 plus the D-form of valine at position 13 resulted in greater anti-inflammatory activity than with the L-form tripeptide. These examples indicate that alterations in the amino acid characteristics of the peptides can influence activity of the peptides or have little effect, depending upon the nature of the manipulation.

It is also believed that biological functional equivalents may be obtained by substitution of amino acids having similar hydropathic values. Thus, for example, isoleucine and leucine, which have a hydropathic index +4.5 and +3.8, respectively, can be substituted for valine, which has a

hydropathic index of +4.2, and still obtain a protein having like biological activity. Alternatively, at the other end of the scale, lysine (-3.9) can be substituted for arginine (-4.5), and so on. In general, it is believed that amino acids can be successfully substituted where such amino acid has a hydropathic score of within about +/- 1 hydropathic index unit of the replaced amino acid.

5

Having described the invention, what is claimed is:

1. A method for reducing the viability of microbes comprising exposing the microbes to an antimicrobial agent selected from the group consisting of one or more peptides including the amino acid sequence KPV, one or more peptides including the amino acid sequence MEHFRWG, or a biologically functional equivalent of any of the foregoing.

2. A method according to Claim 1, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

3. A method according to Claim 2, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV.

4. A method according to Claim 3, wherein the entire amino acid sequence of the antimicrobial agent is KPV.

5. A method according to Claim 1, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence HFRWGKPV or a biologically functional equivalent of any of the foregoing.

6. A method according to Claim 4, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence HFRWGKPV.

7. A method according to Claim 5, wherein the entire amino acid sequence of the antimicrobial agent is HFRWGKPV.

8. A method according to Claim 1, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV or a biologically functional equivalent of any of the foregoing.

9. A method according to Claim 7, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV.

10. A method according to Claim 8, wherein the entire amino acid sequence of the antimicrobial agent is SYSMEHFRWGKPV.

11. A method according to Claim 1, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence MEHFRWG or a biologically functional equivalent of any of the foregoing.

12. A method according to Claim 11, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence MEHFRWG.

13. A method according to Claim 11, wherein the entire amino acid sequence of the antimicrobial agent is MEHFRWG.

14. A method according to Claim 1, wherein the antimicrobial agent excludes naturally occurring α-MSH.

15. A method according to Claim 1, wherein the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to thirteen.

16. A method according to Claim 15, wherein the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to eight.

17. A method according to Claim 1, wherein the antimicrobial agent is N-acetylated and C-amidated.

18. A method according to Claim 1, wherein the concentration of the antimicrobial agent is at least 10^{-12} molar.

19. A method according to Claim 18, wherein the concentration of the antimicrobial agent is at least 10^{-6} molar.

20. A method according to Claim 1, wherein the microbes include *Staphylococcus aureus* or *Candida albicans*.

21. A method for reducing the germination of yeast comprising exposing the yeast to an antimicrobial agent selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

22. A method according to Claim 21, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

23. A method according to Claim 22, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV.

24. A method according to Claim 23, wherein the entire amino acid sequence of the antimicrobial agent is KPV.

25. A method according to Claim 21, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence HFRWGKPV or a biologically functional equivalent of any of the foregoing.

26. A method according to Claim 25, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence HFRWGKPV.

27. A method according to Claim 26, wherein the entire amino acid sequence of the antimicrobial agent is HFRWGKPV.

28. A method according to Claim 21, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV or a biologically functional equivalent of any of the foregoing.

29. A method according to Claim 28, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV.

30. A method according to Claim 29, wherein the entire amino acid sequence of the antimicrobial agent is SYSMEHFRWGKPV.

31. A method according to Claim 21, wherein the antimicrobial agent excludes naturally occurring α-MSH.

32. A method according to Claim 21, wherein the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to thirteen.

33. A method according to Claim 32, wherein the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to eight.

34. A method according to Claim 21, wherein the antimicrobial agent is N-acetylated and C-amidated.

35. A method according to Claim 21, wherein the concentration of the antimicrobial agent is at least 10^{-12} molar.

36. A method according to Claim 35, wherein the concentration of the antimicrobial agent is at least 10^{-6} molar.

37. A method according to Claim 21, wherein the yeasts include *Candida albicans*.

38. A method for killing microbes without reducing the killing of microbes by human neutrophils comprising exposing the microbes to an antimicrobial agent selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

39. A method according to Claim 38, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

40. A method according to Claim 39, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV.

41. A method according to Claim 40, wherein the entire amino acid sequence of the antimicrobial agent is KPV.

42. A method according to Claim 38, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV or a biologically functional equivalent of any of the foregoing.

43. A method according to Claim 42, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV.

44. A method according to Claim 43, wherein the entire amino acid sequence of the antimicrobial agent is SYSMEHFRWGKPV.

45. A method according to Claim 33, wherein the antimicrobial agent excludes naturally occurring α-MSH.

46. A method according to Claim 38, wherein the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to thirteen.

47. A method according to Claim 38, wherein the antimicrobial agent is N-acetylated and C-amidated.

48. A method according to Claim 38, wherein the concentration of the antimicrobial agent is at least 10^{-12} molar.

49. A method according to Claim 48, wherein the concentration of the antimicrobial agent is at least 10^{-6} molar.

50. A method according to Claim 38, wherein the microbes include *Candida albicans*.

51. A method for treating inflammation in which there is microbial infection without reducing microbial killing comprising exposing the microbes to an antimicrobial agent selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

52. A method according to Claim 51, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

53. A method according to Claim 52, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV.

54. A method according to Claim 53, wherein the entire amino acid sequence of the antimicrobial agent is KPV.

55. A method according to Claim 51, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV or a biologically functional equivalent of any of the foregoing.

56. A method according to Claim 55, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV.

57. A method according to Claim 56, wherein the entire amino acid sequence of the antimicrobial agent is SYSMEHFRWGKPV.

58. A method according to Claim 51, wherein the antimicrobial agent excludes naturally occurring α-MSH.

59. A method according to Claim 51, wherein the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to thirteen.

60. A method according to Claim 51, wherein the antimicrobial agent is N-acetylated and C-amidated.

61. A method according to Claim 51, wherein the concentration of the antimicrobial agent is at least 10^{-12} molar.

62. A method according to Claim 61, wherein the concentration of the antimicrobial agent is at least 10^{-6} molar.

63. A method according to Claim 51, wherein the microbes include *Candida albicans*.

64. A method for increasing the accumulation of cAMP in microbes comprising exposing the microbes to an antimicrobial agent selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

65. A method according to Claim 64, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

66. A method according to Claim 65, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV.

67. A method according to Claim 66, wherein the entire amino acid sequence of the antimicrobial agent is KPV.

68. A method according to Claim 64, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV or a biologically functional equivalent of any of the foregoing.

69. A method according to Claim 68, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV.

70. A method according to Claim 69, wherein the entire amino acid sequence of the antimicrobial agent is SYSMEHFRWGKPV.

71. A method according to Claim 64, wherein the antimicrobial agent excludes naturally occurring α-MSH.

72. A method according to Claim 64, wherein the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to thirteen.

73. A method according to Claim 64, wherein the antimicrobial agent is N-acetylated and C-amidated.

74. A method according to Claim 64, wherein the concentration of the antimicrobial agent is at least 10^{-12} molar.

75. A method according to Claim 74, wherein the concentration of the antimicrobial agent is at least 10^{-6} molar.

76. A method according to Claim 64, wherein the microbes include *Candida albicans*.

77. An antimicrobial agent selected from the group consisting of one or more peptides including the amino acid sequence KPV, one or more peptides including the amino acid sequence MEHFRWG, or a biologically functional equivalent of any of the foregoing.

78. An antimicrobial agent according to Claim 77, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV or a biologically functional equivalent of any of the foregoing.

79. An antimicrobial agent according to Claim 78, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV.

80. An antimicrobial agent according to Claim 78, wherein the entire amino acid sequence of the antimicrobial agent is KPV.

81. An antimicrobial agent according to Claim 77, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence HFRWGKPV or a biologically functional equivalent of any of the foregoing.

82. An antimicrobial agent according to Claim 81, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence HFRWGKPV.

83. An antimicrobial agent according to Claim 82, wherein the entire amino acid sequence of the antimicrobial agent is HFRWGKPV.

84. An antimicrobial agent according to Claim 77, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV or a biologically functional equivalent of any of the foregoing.

85. An antimicrobial agent according to Claim 84, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence SYSMEHFRWGKPV.

86. An antimicrobial agent according to Claim 85, wherein the entire amino acid sequence of the antimicrobial agent is SYSMEHFRWGKPV.

87. An antimicrobial agent according to Claim 77, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence MEHFRWG or a biologically functional equivalent of any of the foregoing.

88. An antimicrobial agent according to Claim 87, wherein the antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence MEHFRWG.

88. An antimicrobial agent according to Claim 88, wherein the entire amino acid sequence of the antimicrobial agent is MEHFRWG.

89. An antimicrobial agent according to Claim 77, wherein the antimicrobial agent excludes naturally occurring α-MSH.

90. An antimicrobial agent according to Claim 77, wherein the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to thirteen.

91. An antimicrobial agent according to Claim 90, wherein the antimicrobial agent is further selected from the group consisting of one or more peptides having an amino acid chain length of up to eight.

92. An antimicrobial agent according to Claim 77, wherein the antimicrobial agent is N-acetylated and C-amidated.

93. An antimicrobial agent according to Claim 77, wherein the concentration of the antimicrobial agent is at least 10^{-12} molar.

94. An antimicrobial agent according to Claim 93, wherein the concentration of the antimicrobial agent is at least 10^{-6} molar.

95. An antimicrobial agent according to Claim 77, wherein the antimicrobial agent is effective against microbes including *Staphylococcus aureus* or *Candida albicans*.

ABSTRACT OF THE DISCLOSURE

The presence of the ancient anti-inflammatory peptide α-melanocyte stimulating hormone (α-MSH [1-13], SYSMEHFRWGKPV) in barrier organs such as gut and skin suggests a role in the nonspecific (innate) host defense system. α-MSH and other amino acid sequences derived from α-MSH were determined to have antimicrobial influences, including against two major and representative cutaneous and mucosal pathogens: *Staphylococcus aureus* and *Candida albicans*. α-MSH peptides had antimicrobial effects against *S. aureus* and significantly reversed the enhancing effect of urokinase on *S. aureus* colony formation. α-MSH and other amino acid sequences reduced *C. albicans* viability and germination. α-MSH peptides also enhanced *C. albicans* killing by human neutrophils. The antimicrobial agent is selected from the group consisting of one or more peptides including the amino acid sequence KPV, one or more peptides including the amino acid sequence MEHFRWG, or a biologically functional equivalent of any of the foregoing. The most effective of the peptides were those bearing the C-terminal amino acid sequence of α-MSH, i.e., α-MSH (1-13), (6-13), and (11-13). The α-MSH "core" sequence (4-10), important for melanotropic effects, was also effective but significantly less potent. Antimicrobial influences of α-MSH peptides could be mediated by their well-known capacity to increase cellular cAMP; this messenger was significantly augmented in peptide-treated yeast. α-MSH has potent anti-inflammatory effects and is expected to be useful for treatment of inflammation in human and veterinary disorders. Reduced killing of pathogens is a detrimental consequence of therapy with corticosteroids and nonsteroidal anti-inflammatory drugs during infection. Therefore, anti-inflammatory agents based on α-MSH peptides that do not reduce microbial killing, but rather enhance it, would be very useful. The antimicrobial effects of these α-MSH peptides occurred over a broad range of concentrations including the physiological (picomolar) range.